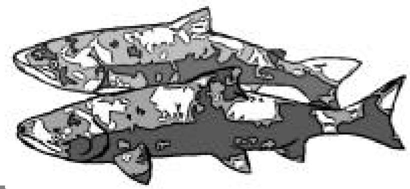
Part Two
Region-wide
Factors For Decline



2.1 Introduction

> ***"The basic approach is to examine a variety of region-wide factors potentially affecting production, both natural and human caused, to identify those that change in concert with the recent summer chum salmon decline."***

Like all Pacific salmon, summer chum salmon are influenced by a variety of factors, with both positive and negative consequences for their overall survival. Part Two provides a general analysis of those factors that most likely have been responsible for the abrupt decline in summer chum salmon abundance that has occurred in Hood Canal streams in the late 1970s and in Strait of Juan de Fuca streams a decade later. The basic approach is to examine a variety of region-wide factors potentially affecting production, both natural and human caused, to identify those that change in concert with the recent summer chum salmon decline. Part Three of this recovery plan will identify more specific factors for decline and will present recovery strategies, under the general categories of artificial production, ecological interactions, habitat, and harvest management.

While this discussion focuses on individual factors for decline, the observed reductions in the numbers of summer chum salmon in the region are the result of the combined impacts of a number of factors. When two or more impacts occur that negatively affect the survival or the resilience of a salmon population there may be a synergistic effect, where there is a greater overall loss than an observed change in an individual survival factor. An example of such an amplification of impacts might be if a habitat alteration substantially reduces the incubation survival of the eggs and alevins in a stream (e.g., through increased siltation or flooding), and the subsequent predation on the surviving fry becomes higher than normal because predators take an increased proportion of the reduced prey population. The combined impact (total mortality) would be higher than just the change in incubation survival would suggest.

The factors identified here may not include all of the elements that need to be addressed for recovery of these summer chum stocks. Those factors implicated in the recent abrupt decline of summer chum salmon will not necessarily include those effects that over time, gradually and cumulatively impact salmon survivals. For example, there has been a long history of negative anthropogenic habitat-related impacts affecting salmon populations, and many of these have occurred prior to the period of decline addressed here (section 3.4). Additionally, nearly two decades have passed since the beginning of the decline of summer chum, and a broader range of negative conditions now exist. All known negative factors must be addressed to effect the recovery, stability, and sustainability of Hood Canal and the Strait of Juan de Fuca summer chum salmon stocks.

2.2 Negative Impacts On Abundance

2.2.1 Introduction

The following section will examine those factors that can influence summer chum salmon abundance in an attempt to identify specific sources of mortality that have contributed to the declines of Hood Canal and the Strait of Juan de Fuca summer chum salmon. There are several general conclusions, however, that can be reached through a simple examination of the escapement data and run size data in Table 1.5 and Table 1.6 (see section 1.5, Period of Decline discussion in Part One). First, the factors for decline are probably different for the two regions involved; Hood Canal and the Strait of Juan de Fuca. The drop in abundance of summer chum salmon has occurred ten years apart in the two regions; 1979 for Hood Canal streams, versus 1989 for Strait of Juan de Fuca streams. This is probably because of differences in these regions; they have distinctly different climates, stream habitat types, habitat problems, and fishery exploitation patterns. The second observation is that the data suggest that the factors for decline affect every chum salmon return year, and do not seem to have a short term cyclic component. This information is useful because short term cyclic effects can be discounted in the following examination of limiting factors (e.g., the every other year presence of pink salmon can be eliminated as a potential negative impact). If there is a cyclic element involved in the decline of summer chum salmon, it likely has a decadal or longer pulse.

Potential factors affecting production will be examined individually in the following four categories: 1) climate, 2) ecological interactions, 3) habitat, and 4) harvest. This section will end with a conclusions discussion that will examine the combined impacts of factors for decline, and will evaluate the relative importance of various factors.

2.2.2 Climate

The weak returns of summer chum salmon in 1979 to both Hood Canal and Strait of Juan de Fuca streams reflected a broad failure of nearly all Washington State wild summer and fall chum stocks. All regions of the state experienced record low returns of chum salmon, and the statewide harvest in 1979 was the lowest recorded for the species in 60 years (Johnson et al. 1997). The Strait of Juan de Fuca and Union River (Hood Canal) summer chum salmon stocks immediately recovered from the low returns in 1979, but the other populations of summer chum salmon in Hood Canal failed to recover and in most cases declined further over the next several years. The Strait of Juan de Fuca stocks began to decline a decade later. This pattern of major decline and subsequent continuing low population abundance beginning in Hood Canal in 1979 was relatively consistent across a number of streams with varying environments and habitat types. The uniform nature of these declines suggests the need to assess the possibility of a regional environmental impact, in fresh and/or marine waters.

Local stocks of summer chum salmon may be particularly susceptible to changes in climate. These fish are the southernmost representatives of summer-timed chum salmon in the northeast Pacific region, may naturally lead a somewhat tenuous existence, and may be less resilient when facing a changing environment. Changes in ocean, estuarine, or freshwater conditions that may have a modest impact on fall chum salmon could be a major limiting factor for summer chum salmon.

2.2.2.1 Ocean Effects (ENSO and PDO)

The phenomena of the El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) have received a great deal of recent attention in the Pacific Northwest (PNW) fisheries community because of increasing evidence that these fluctuations in ocean conditions can have profound effects on the growth and survival of Pacific salmon and other types of fish (see Emmett and Schiewe 1997).

El Niño-Southern Oscillation events begin as warming episodes in the tropical Pacific zone and can result in large scale intrusions of anomalously warm marine water northward along the PNW coastline. The effects of these warm water intrusions are felt along the Washington and British Columbia coast for a one to two year duration in an irregular periodicity of every two to seven years (Mysak 1986). ENSO episodes vary greatly in intensity, and have been shown to impact salmonid marine growth and survival (e. g. food abundance and predator impacts change), and can additionally affect the freshwater environment. ENSO impacts on salmonid growth and survival can vary by species and locale (e. g., negative for Oregon coastal coho salmon (Pearcy 1992), positive for British Columbia sockeye salmon (Mysak 1986)). ENSO conditions are associated with generally warmer and drier weather conditions along the PNW coastal zone, and can cause reduced snow pack and lower stream flows in western Washington State (Mantua, undated).

El Niño-Southern Oscillation (ENSO)

A climate event that begins as a warming episode in the tropical Pacific zone and can result in large scale intrusions of anomalously warm marine water northward along the PNW coastline.

The Pacific Decadal Oscillation is a pattern of climate and ocean condition regimes occurring in the north Pacific Ocean (associated with the Aleutian low pressure system) that results in shifts in sea surface temperatures and plankton abundance on a decadal time scale (Mantua et al. 1997). The 20 to 40 year regimes in the PDO have been shown to relate directly to the abundance of Alaskan pink and sockeye salmon (Francis and Hare 1997). The most recent shift occurred in 1977 (Ebbesmeyer et al. 1989), and resulted in warmer coastal sea temperatures, cooler central Pacific sea temperatures, and more abundant plankton resources which contributed to

Pacific Decadal Oscillation (PDO)

A pattern of climate and ocean condition regimes occurring in the north Pacific Ocean (associated with the Aleutian low pressure system) that results in shifts in sea surface temperatures and plankton abundance on a decadal time scale.

strong returns of Alaskan salmon in the last two decades (Francis and Hare 1997). The most recent PDO shift has been shown to relate to general increases in production of pink, chum and sockeye salmon in the North Pacific Ocean (Beamish and Bouillion 1993), and more specifically to Fraser River sockeye salmon (Beamish et al. 1997). While the PDO can have a substantial effect on the growth and survival of salmon during their migrations and feeding in the north Pacific Ocean, the phenomenon can also have a major influence on the freshwater environment along the PNW coast, including Washington State. Air temperatures, wind conditions, and precipitation are locally affected by the PDO (Mantua et al. 1997).

The influence of PDO regime shifts on the abundance of zooplankton and on subsequent salmon production in the North Pacific Ocean has been demonstrated (Francis and Hare 1997). The available data for Hood Canal and Strait of Juan de Fuca summer chum salmon are insufficient to examine the possibility of impacts of PDO changes on the marine survivals of these fish. However, naturally produced fall chum stocks in Puget Sound and Hood Canal have increased in abundance since 1977, and now approach historic levels (Johnson et al. 1997). Additionally, returns of fall chum salmon to established Puget Sound hatchery facilities (e.g., Hoodsport, and Minter Creek), show that marine survivals following the PDO shift in 1977 ranged from normal to above normal. If we assume fall and summer chum salmon are subject to similar ocean effects, the success of fall chum salmon would suggest that unusual ocean mortality has not contributed to the summer chum salmon declines. The success of fall chum salmon also seems to discount the possibility that ENSO events have negatively impacted marine survivals, and thus it appears to be unlikely that ENSO related ocean survival conditions are a significant contributor to the decline of summer chum salmon.

2.2.2.2 Estuarine Effects

Ebbesmeyer et al. (1989) has described the relationship between PDO regimes and conditions in the Puget Sound region; showing linkages with patterns of precipitation, freshwater runoff, saltwater temperatures, and currents in Puget Sound. Since 1977, the PDO has been in a positive state, which correlates with less precipitation in western Washington, decreasing freshwater runoff, and faster inflow of marine water into the Puget Sound basin from mid-depth to bottom. These factors could change conditions in estuarine areas of Hood Canal and Strait of Juan de Fuca, and alteration of conditions that potentially affect the survivals of summer chum salmon (e.g., estuarine temperature, salinity, or food production), may have contributed to the observed declines. There are, however, no data available to measure such change, and like ocean effects, the influence of estuarine conditions on summer chum survivals is currently not known.

2.2.2.3 Freshwater Effects

Stream flows are a primary force controlling the survival of salmon in the stream environment. For summer chum salmon, the critical periods are during spawning (September - October) and during the intragravel incubation of eggs and alevins (November - March). Since chum salmon juveniles do not typically rear in freshwater, stream flows during the spring and summer months presumably have less impact on survivals, possibly influencing fry emigration (February - April) and the upstream migration of the earliest arriving adults in August. The following examination of stream flow impacts on summer chum salmon will focus on the spawning and incubation periods.

Because adult summer chum salmon enter streams and spawn during the lowest flow period of the year, they are particularly vulnerable to any reductions in stream flow. Severely low flows can limit access to the better spawning sites within the stream channel; causing spawning salmon to utilize sub-optimum areas, which can result in reduced egg to fry survivals (Ames and Beecher 1995). The possible negative consequences of poor redd site selection can be reduced egg and alevin survivals because of factors like inadequate intergravel flow and increased exposure to the effects of winter floods.

Winter stream flows can have substantial adverse effects on chum salmon survival, associated with the mortality of incubating eggs and alevins caused by streambed scouring and increased siltation. The nature of flow related impacts on incubating chum salmon eggs and alevins has been defined for chum salmon at Big Qualicum River, British Columbia by Lister and Walker (1966) (see Table 2.1). They demonstrate an inverse relationship between incubation survival and the peak flow that occurs during incubation, with egg to fry survivals at Big Qualicum varying fivefold; from 25% with no flood, to 5% with flood conditions. The authors identify instream flow and resultant streambed scour to be the major factor influencing the freshwater survival rate of chum salmon.

The same flow/survival relationship has also been shown for salmonids in Washington State; sockeye salmon in the Cedar River (Thorne and Ames 1987), and chinook and coho salmon in the Skagit and Clearwater rivers respectively (Dave Seiler, WDFW, personal communication). The mechanics of stream bed scour and the effects on chum salmon egg pockets and intergravel survival are described by Montgomery et al. (1996) from studies on Kennedy Creek in southern Puget Sound. Any changes in the magnitude of winter flows can have a direct effect on the success of summer chum salmon.

Table 2.1. Chum salmon survival from actual egg deposition to fry migration in relation to discharge extremes during incubation, Big Qualicum River, 1959-64 (from Lister and Walker 1966).

Maximum daily discharge (cfs) during incubation	Percent survival	(brood year)
393	25.2	(1964)
800	25.9	(1963)
1,260	17.8	(1961)
1,360	18.2	(1959)
2,000	9.6	(1962)
3,200	5.3	(1960)

For the present analysis, U.S. Geological Survey (USGS) stream discharge records have been examined to look for possible relationships between summer chum salmon abundance and the effects of climate on critical stream flows (Appendix Table 2.1). Several stream discharge data bases have been examined for 1) any evidence explaining the abrupt drop in Hood Canal summer chum salmon in 1979, 2) any relationship between flows and the 1989 drop in Strait of Juan de Fuca summer chum salmon abundance, and 3) any general changes in stream flows that relate to the PDO shift in 1977. The absence of survival rate data for summer chum salmon precludes the use of traditional correlation analyses to examine the possible relationships between stream flows and the survivals of summer chum salmon. Instead, variations in mean flows for periods of years before and after observed changes in the climate or summer chum salmon abundance have been examined. Any evidence of change, or lack of change, in the stream flow data has been tested for statistical significance (one tailed t-test).

Puget Sound Stream Flow Index - Gallagher (1979) has developed a data base of freshwater and marine environmental variables for his study of the factors affecting the life histories of Puget Sound chum and pink salmon. WDFW annually updates, and in some cases modifies, this database for use in forecasting annual returns of chum and pink salmon to Puget Sound. One of the more useful stream discharge parameters that has been developed by Gallagher is the percent deviation from the mean of the lowest and highest ten consecutive days of stream flow, derived from stream discharge data from a number of USGS stream gages on major river systems in the Puget Sound region. This Puget Sound Stream Flow Index (PSSFI) data base has not been updated in recent years, however the 1959 through 1991 water years are represented (Appendix Table 2.1). The current PSSFI assembles stream flow data from nine stream gages (Table 2.2) for several periods corresponding to summer chum salmon spawning (September 15 - November 14), and incubation stages (November 15 - February 14).

Table 2.2. USGS stream gages included in the Puget Sound Stream Flow Index.

North Fork Nooksack River at Glacier	Puyallup River at Puyallup
Skagit River at Concrete	Skokomish River at Potlatch
Skykomish River at Gold Bar	North Fork Skokomish near Potlatch
Snoqualmie River at Carnation	Duckabush River near Brinnon
Puyallup River at Orting	

The PSSFI shows changes in low flows (spawning) that may relate to the recent PDO shift. The average 10-day low flows (Sept. 15 - Nov. 14) coinciding with the summer chum salmon spawning period dropped in the mid-1970s (Appendix Figure 2.1). A comparison of the low flows during the first 18 years (1959-1976) of the PSSFI data base with the most recent 15 year period (1977- 1991) shows a statistically significant change (Appendix Figure 2.1). The average pre-1977 low flows are higher than normal (+9.5% deviation from the mean), while the 1977-1991 low flows are substantially lower than the overall mean (-11.5% deviation from the mean). For post-1976 years 11 of 15 years have 10-day low flows below the 1959-1991 average. For the winter high flow period (Nov. 15 - Feb. 14), the PSSFI shows a weaker potential response to the PDO shift. The higher average 10-day flows from 1959 to 1976 (+6.4% deviation from the mean), change to lower average flows for the post-1976 years (-7.7% deviation from the mean) (non-significant; Appendix Figure 2.2). Nine of 15 years are below the mean during this later period.

These shifts to lower Puget Sound stream flows during the summer chum salmon spawning and incubation periods appear to occur in concert with the 1977 regime shift in the ocean climate cycle, and also seem to correspond with the decline of Hood Canal summer chum salmon. Another measure of stream flow, peak momentary discharge from the same nine USGS gaging stations (1959-1991), does not appear to relate to the PDO regime shift, showing an approximately equal frequency of above average peak flow events before and after 1977.

Hood Canal and Strait of Juan de Fuca stream flows - While the PSSFI data seem to show a link between the PDO and stream flows during the summer chum salmon spawning season, a more direct examination of local Hood Canal and Strait of Juan de Fuca stream flows is needed to identify specific conditions affecting summer chum salmon stocks. There are just three USGS stream gages on the region's streams that are pertinent to summer chum salmon, and have been in operation from the 1960s to present; Big Beef Creek, the Duckabush River, and the Dungeness River.

Spawning flows - Mean monthly stream discharge data for the September-October summer chum salmon spawning period have been examined for the three streams. The 1968 through 1993 years have been selected for this analysis because that range of years encompasses the period of the chum salmon data base available for these streams. There are two missing years for Big Beef Creek (1968 and 1982), while the Duckabush and Dungeness rivers have a continuous record for the period (Appendix Table 2.1). Even though these are the only streams with available stream flow records, they can be considered to be representative of the summer chum salmon streams in Hood Canal and the Strait of Juan de Fuca.

Big Beef Creek is a small lowland stream that originates in the central Kitsap Peninsula at an elevation of just under 500 feet, and flows northwesterly for ten miles to enter the east shore of Hood Canal. Mean annual stream discharge ranges from 30 to 50 cfs (Williams et al. 1975). The watershed has undergone past logging, and is now experiencing substantial road and home construction. In contrast, the Duckabush River has its origin high in the Olympic Peninsula, at an elevation of over 5,200 feet. The river flows for just over 24 miles in an easterly direction, entering the west shore of Hood Canal. The upper 12.6 miles (RM 11.5-24.1), and numerous tributaries, are located in the Olympic National Park, 9.2 miles (RM 2.3-11.5) are in the Olympic National Forest, and the lower 2.3 miles flow through mostly private lands. Average annual stream flow is slightly more than 400 cfs (Johnson et al. 1997). Below the Park boundary, logging has prevailed on Forest Service land, and some home development has occurred along the lower river.

There are no USGS flow gages on the summer chum salmon streams of Discovery and Sequim bays. To examine eastern Strait of Juan de Fuca stream flow patterns, two sources of data have been used; the USGS gage on the Dungeness River, and stream flow data collected at the WDFW Snow Creek Research Station for the years 1977-1992 and 1994 (Appendix Table 2.1, provided by T. H. Johnson and R. Cooper, WDFW).

Both Snow Creek and the Dungeness River support summer chum salmon, however, the two streams are very different in character. Snow Creek is a small, lowland stream that originates in the foothills of the Olympic Mountains at an approximate elevation of 2,900 feet, and flows east and north for 10.1 miles to its confluence with Discovery Bay. The creek is characterized by low stream flow resulting from the influence of the rain shadow effect of the Olympic Mountain range. The headwaters of Snow Creek (above RM 6.75) are in the Olympic National Forest and are subject to periodic logging impacts (Williams et al. 1975). Lower basin land use includes farmland and rural home development. The Dungeness River originates at an elevation of approximately 6,600 feet in the Olympic Mountains and flows north for nearly 32 miles to its mouth on the Strait of Juan de Fuca. Average annual Dungeness River flow is just under 400 cfs (Johnson et al. 1997). A major tributary, the Gray Wolf River, joins the Dungeness 15.8 miles above its mouth. Both streams originate high in the Olympic Mountains, and snow melt contributes to summer and early fall stream flows. The entire basin above RM 13.4 is in the Olympic National Forest and Park

(Williams et al. 1975). Land use patterns include substantial logging on Forest Service lands, and rural farm and home development in the lower basin.

The mean September-October flows for Big Beef Creek, and the Duckabush and Dungeness rivers do not drop in 1977 in relationship to the PDO shift, but instead display relatively uniform flows until a substantial reduction in 1986 and subsequent years. Average September-October stream flow declines from 10.8 cfs (1968-1985) to 4.6 cfs (1986-1993) at Big Beef Creek, from an average of 241 to 122 cfs for the same time periods at Duckabush River, and from 203 to 134 cfs at the Dungeness River. The changes in spawning flows after 1986 are statistically significant for each of the three streams (Appendix Figures 2.3-2.5). The Snow Creek data begin in 1977 and cannot be used to examine the PDO effect.

Table 2.3 partitions the mean September-October flows into three periods for comparison; 1968-1976, 1977-1985, and 1986- 1993. The flows for the two periods, 1968-1976 and 1977-1985, are not statistically different for Big Beef Creek, the Duckabush River, and the Dungeness River (Appendix Table 2.2). The drop in discharge during the 1986-1993 period is severe; Big Beef Creek down 57%, the Duckabush River down 49%, and the Dungeness River down 34%. These differences are statistically significant (Appendix Figure 2.3-2.5). Snow Creek follows the same pattern with a statistically significant drop from a mean flow of 6.6 cfs (1977-1985) to an 1986-1993 mean flow of 3.6 cfs (Appendix Figure 2.6), a 45% decline. With the very different geomorphology and land use patterns of the four basins, the similar magnitude of the changes in flow in the individual streams suggests a broad climatic change as the primary cause for the reduction in discharges.

Table 2.3. Mean flow in cfs during September and October in four steams in the Hood Canal and Strait of Juan de Fuca region (1968-1993), with (n) = number of years available data.

Stream		Mean flow 1968-1976	Mean flow 1977-1985	Mean flow 1986-1993
Big Beef Cr.	- mean	10.9 (8)	10.7 (8)	4.6 (8)
	- range	5.0 - 35.8	5.4 -24.6	3.1 - 6.5
Duckabush R.	- mean	210.0 (9)	272.9 (9)	121.9 (8)
	- range	101 - 489	90 - 376	54 -214
Snow Cr.	- mean	no data	6.6 (9)	3.6 (7)
	- range		1.4 - 13.6	1.8 -7.7
Dungeness R.	- mean	194.8 (9)	211.0 (9)	134.0 (6)
	- range	133 - 320	149 - 260	99 - 167

Incubation flows - For Hood Canal and Strait of Juan de Fuca summer chum salmon streams, only the USGS gages on the Duckabush and Dungeness rivers provide a continuous year-round discharge record for time periods before and after the PDO shift. It is assumed that the Dungeness River is reasonably representative of flow patterns for eastern Strait of Juan de Fuca summer chum salmon streams. Snow Creek flow data are not suitable for this analysis because the flow record begins in 1977.

The annual peak instantaneous discharges for both rivers (Appendix Table 2.2) have been examined for evidence of changes in incubation period (October-March) flow patterns during the 1968-1995 span of years. The average Duckabush River peak instantaneous flow during the nine years preceding the 1977 PDO shift (3,864 cfs) is lower than the same value calculated for the 19 years following the shift (5,064 cfs) (Appendix Figure 2.7). The Dungeness River has an average peak flow of 2,437 cfs for the 1968-1976 period that increases to an average peak flow of 3,776 cfs from 1977 to 1995 (Appendix Figure 2.8). The pattern of peak flows is similar for both rivers; substantially higher average peak flows for the years since the regime shift. The flow change for the Duckabush is not statistically significant, while the change in Dungeness River flow is statistically different (Appendix Table 2.2).

Table 2.4 splits the peak flow data into three periods (1968-1976, 1977-1985, and 1986-1995) to examine the relationship between pre-PDO shift flows and two time periods for subsequent years. Average peak flows are substantially higher for both time periods following the regime shift, however, there is no indication of a shift in peak flows in 1986 corresponding to the observed change in spawning flows (Appendix Table 2.2). This result seems to contradict the pattern of positive PDO regimes causing warmer, drier weather conditions in the PNW region, and is also contrary to the PSSFI data (see above) which shows a reduction in 10-day winter high flows after the regime shift. It may be that during warmer conditions, precipitation from major Pacific storms takes the form of more intense rain events with less snow fall, resulting in faster runoff and greater peak stream flow events.

Table 2.4. Mean and range of peak instantaneous flows in cfs in the Duckabush and Dungeness rivers occurring between October and March (1968-1995), with (n) = number of years available data.

Stream		Peak flow 1968-1976	Peak flow 1977-1985	Peak flow 1986-1995
Duckabush R.	- mean	3,864 (9)	5,364 (9)	4,793 (10)
	- range	1,360-6,090	2,160-7,820	1,910-9,240
Dungeness R.	- mean	2,437 (9)	3,768 (9)	3,783 (10)
	- range	597-5,150	1,460-6,550	1,300-7,120

2.2.2.4 Conclusions

Climate and its effects on ocean processes and weather is a complex subject, and the above analysis is only intended to identify general patterns of climate that may have contributed to the changes in summer chum salmon status. The following discussion and Table 2.5 are summarizations of the possible effects of climate change and the potential effects on summer chum salmon.

Ocean Effects

Because of the lack of specific summer chum salmon survival data, the potential impacts of changes in ocean productivity related to ENSO events and PDO regime shifts cannot be determined at this time.

Table 2.5. Summary of observed changes in Puget Sound (PSSFI), Hood Canal, and Strait of Juan de Fuca stream flows.

The 1977 PDO regime shift -
Ocean productivity effects on summer chum salmon survivals are not measurable due to lack of stock production data.

Stream flows that changed with the 1977 PDO regime shift:

- 10-day low spawning flows declined (Sept. 15 - Nov. 14) for PSSFI.
- 10-day high incubation flows declined (Nov. 15 - Feb 14) for PSSFI.
- Peak instantaneous incubation flows increased in the Duckabush and Dungeness rivers (Oct.-Mar.).

The 1986 flow reductions -
Stream flows that changed in 1986:

- Mean spawning flows declined in Big Beef and Snow creeks, and Duckabush and Dungeness rivers (Sept.-Oct.).

Estuarine Effects

Regional climate patterns (e.g., rainfall and air temperatures) have been shown to be affected by changes in ocean conditions related to ENSO events and shifts in the PDO. These are the type of changes that can influence the productive capacity of estuaries, however, at this time it is not known to what degree these climate shifts may or may not have contributed to the decline of summer chum stocks.

Freshwater Effects

Spawning flows - Along with major ocean changes, shifts in the PDO have been shown to affect Puget Sound weather, precipitation, and run-off (Ebbesmeyer et al. 1989). In the current "positive" PDO state, precipitation and resultant stream discharges would be expected to be lower than average. While the Puget Sound Stream Flow Index shows a drop in spawning season low flows that corresponds to the 1977 PDO regime shift, Hood Canal and Strait of Juan de Fuca streams have had stable September-October mean flows through this period of climate change. A notable drop in stream flows in the region has occurred, however, in 1986 and flows have continued to be lower in subsequent years.

Two obvious questions are: 1) why does the PSSFI spawning flow index correlate with the PDO shift while the Hood Canal and Strait of Juan de Fuca streams do not show a similar relationship, and 2) do PSSFI spawning flows show the 1986 drop in stream flows?

The PSSFI percent deviation from the mean 10-day low flow statistic is dominated by measurements from large river systems (e.g. the Skagit and Puyallup rivers) whose late summer spawning flows may be largely influenced by a combination of snow melt, precipitation, and groundwater. In contrast, Big Beef Creek and the Duckabush River September and October flows are more likely to result from precipitation and groundwater, and without a substantial contribution from snow melt, may be less affected by the PDO climate shift. Summer stream flows in the Dungeness River are affected by snow melt runoff, but September-October flows are lower and likely more the result of local precipitation and groundwater contributions.

The 1986 drop in stream discharge during the spawning season is apparent in the PSSFI flows. As discussed above, there has been a clear drop in the PSSFI after 1976 (see Appendix Figure 2.1), however, the two greatest negative deviations from the mean flow occurred in 1986 and 1987, -31.73% and -45.43% respectively. The PSSFI does not continue at this lower level, however, showing values averaging -4.9% for the four year period of 1988-1991. The 1986 drop in streams flows may not be evident in the PSSFI as a continuing condition because of the influence of late summer snow melt in the large streams included in this index.

Incubation flows - A fundamental change in peak winter flows has occurred in concert with the 1977 PDO shift in Hood Canal and Strait of Juan de Fuca streams. Peak instantaneous discharge during the summer chum salmon incubation period (October-March) has increased substantially, as measured on the Duckabush (+31%) and Dungeness (+ 55%) rivers. As stated above, this outcome seems opposed to the expected pattern of warmer, dryer weather with the current positive PDO regime, but this apparent anomaly may result from differences in the amount of precipitation that falls in the form of rainfall (and less as snowfall) from individual storm events.

Climate Impacts on Summer Chum Salmon

Hood Canal - The decline of Hood Canal summer chum salmon begins with the 1979 adult return, which is primarily composed of 1976 brood age-3 fish and 1975 brood age-4 fish. Hood Canal summer chum salmon from the 1975 and 1976 broods were at sea for 2-3 years after the regime shift, and it is possible that their marine survivals were negatively impacted. There are no direct summer chum salmon data available to support or refute the possibility of lower marine survivals, however, the recent success of fall chum salmon in the region suggests that it is unlikely that changes in marine survival significantly contributed to the decline.

The increase in peak incubation flows after the PDO shift is substantial (+31% for the Duckabush River), and increased flow related mortalities of incubating eggs and alevins is a likely result. The elevated incubation flows may well have been a contributing factor to the lack of recovery and continued decline of Hood Canal summer chum salmon in the early 1980s. Since ENSO events have the same type of effects as the current positive PDO state on regional weather patterns (warmer and drier conditions), both conditions could affect stream flows.

Increased intra-redd mortality resulting from higher incubation flows could have been exacerbated by the major reduction in spawning flows that occurred in 1986 and subsequent years. The major decline in average stream flows that occurred in September/October stream flows (-57% at Big Beef Creek and -49% at Duckabush River) has several potentially serious consequences for summer chum salmon. The early return and spawning timing of summer chum salmon makes them particularly vulnerable to reductions in stream flow. Low flows and elevated water temperatures could delay the entry of the fish to spawning streams, which could increase their susceptibility to fishery exploitation and predation. Once in the stream, they would be forced to spawn in mid-channel areas, exposing resulting eggs and alevins to increased levels of mortality during subsequent high flow events. A continuation of the combination of low flow patterns during spawning and elevated incubation flows of recent years could slow the recovery rate of Hood Canal summer chum salmon.

Strait of Juan de Fuca - The summer chum salmon stocks of the eastern Strait of Juan de Fuca have recovered quickly from the low 1979 return, and have displayed good returns until the major decline in 1989. As with Hood Canal streams, the Dungeness River shows no change in September/October flows coinciding with the 1977 PDO shift. The 1986 severe drop in spawning flows seen in the Hood Canal region also has occurred in Strait of Juan de Fuca streams, and may have substantially impacted local summer chum salmon stocks. Stream discharge data from Snow Creek show a drop in September/October flows of 45%, and Dungeness River flows for the same months have declined 34%.

Snow, Salmon, and Jimmycomelately creeks are small streams that are located in the rain shadow of the Olympic Mountain range, and experience extremely low flows during the summer chum salmon spawning season. For example, the mean September/October flow on Snow Creek from 1977 to 1985 is only 6.6 cfs. The reduction in Snow Creek spawning flows to an average of 3.8 cfs from 1986 to 1993, has the potential to cause a major reduction in summer chum salmon survivals and returns. Extreme low flows during the spawning period can jeopardize survival by:

- increasing prespawning mortality of adults by restricting or delaying access to freshwater;
- increasing prespawning mortality of adults in the stream through exposing the spawners to higher than normal predation levels;
- increasing prespawning mortality of adults in the stream because of elevated water temperatures; and
- increasing mortality of incubating eggs and alevins because of limited spawner access to optimum spawning sites.

The offspring of the summer chum salmon that spawned in eastern Strait of Juan de Fuca streams in 1986 first returned as age-3 fish in 1989. For the 1990 return, and subsequent years, the returning fish have all been subjected to the impacts of the reduced spawning and increased incubation flows. The limited nature of the freshwater habitat in the region, the small size of the individual spawning streams, and the early run-timing of the summer chum stocks, combine to give the observed changes in local stream flow regimes the potential to have had a strong negative impact on the success of the summer chum salmon. It is likely that the effects of climate on Strait of Juan de Fuca stream flows has contributed to the decline in summer chum salmon stock status.

As with Hood Canal summer chum salmon, there are insufficient data available for the Strait of Juan de Fuca fish to evaluate potential PDO and ENSO effects on marine survivals.

Climate in Relation to Human Caused Impacts

Any analysis of climate change in relation to stream flow and summer chum populations cannot be isolated from a consideration of human-caused habitat alterations. It is significant to note that prior to significant human impact to their habitat, summer chum populations have persisted in the face of natural climate fluctuations. Over the last 150 years, however, human development impacts have produced incremental and gradual, but cumulatively significant changes to Hood Canal and Strait of Juan de Fuca watersheds. These changes have altered the resiliency of salmon habitat in the face of these climate fluctuations. Historically, diverse and resilient habitats buffered summer chum populations against the effects of deleterious climate shifts. Stream channels contained abundant LWD with sufficient stable spawning, incubation, and migration habitats. Riparian forests, intact floodplains, wetlands, and alluvial aquifers moderated stream flows against seasonal extremes.

The climate-driven changes in hydrology described above (decreases in spawning season stream flows since 1986 and increases in instantaneous peak discharge during the incubation period since 1977) are even more significant when we consider how they interact with human impacts to summer chum habitat. Water withdrawal from streams or aquifers that are in hydrologic continuity with summer chum streams has further increased the severity of low flows. Removal of streamside vegetation has reduced the thermal insulating capacity of riparian zones and resulted in elevated water temperatures during the summer chum spawning season. In addition, loss of wetlands and critical aquifer recharge areas to development has likely further exacerbated low flows by eliminating natural groundwater recharge that augments stream flows during the summer.

Floodplain development and stream bank armoring has altered the impact of peak flow events on incubating summer chum salmon through the loss of flood storage capacity and the confinement of flood flows to the main channel. Removal of LWD from stream channels has reduced bed stability and scour resistance. Both LWD removal and the confinement of flood flows to the main channel have increased the frequency and severity of streambed scour with negative consequences for summer chum incubation survival.

Human changes to Hood Canal/Strait of Juan de Fuca stream ecosystems have thus diminished the natural resiliency of summer chum habitat, rendering populations more vulnerable to climate shifts. Climate shifts like those observed in the past 30 years, with their associated stream flow changes, likely have posed little threat to summer chum populations before the cumulative effects of habitat changes from human development became manifest. There are no streams within the region that have escaped such mistreatment, thus disentangling climate from human-induced impacts is highly problematic.

2.2.3 Ecological Interactions

The interactions of summer chum salmon with various species of fish, birds, and mammals is a normal part of their life history, and usually are in a state of dynamic equilibrium with co-evolved species. While these interactions include factors like nutrient contribution and cover, this discussion will focus only on competition for living space and food resources, and predation of one species on another. Fresh (1997) points out that extraordinary competition or predation impacts on salmonids are often the consequence of an alteration of the natural life history processes of the interacting species. For example, hatchery programs can increase the numbers of potential competitors and/or predators, or over-harvest can reduce population abundance to the point that predation mortality becomes depensatory, and holds prey populations at a very low level.

In a review of the available literature dealing with the effects of competition and predation on Pacific salmon, Fresh (1997) reports that; "... 33 fish species, 13 bird species, and 16 marine mammal species are predators of juvenile and adult salmon." Emmett et al. (1991) state about juvenile chum salmon: "In freshwater and estuarine environments, this species' primary predators are probably other salmonids." Salo (1991) reviews a variety of studies which showed freshwater predation mortality rates for chum salmon fry averaging from 22-58%, with extreme ranges of 2-85%. Major freshwater predator species identified include; coho salmon, cottids, trout, and char. Predation is the primary cause of chum fry mortality in the estuarine environment; with major predators being other salmonids, various nearshore marine fish species, and a variety of predatory birds (Emmett et al. 1991). At sea, lamprey, shark, other large predatory fish, and several types of marine mammals are the most significant predators (Emmett et al. 1991).

A variety of fish species potentially can compete for food resources with chum salmon, however, Bakkala (1970) states that the other species of Pacific salmon are principle competitors of chum salmon. The effects of this competition between salmon species can be substantial, as evidenced by the strong two year cycles in chum salmon abundance when the juvenile chum salmon compete for common food resources with biennially abundant pink salmon juveniles (Gallagher 1979, Ames 1983, Salo 1991, Johnson et al. 1997). Salmonids can also compete for spawning sites when adult run timing and spawning distributions overlap (Bakkala 1970).

Conspecific competition with fall chums, of both wild and hatchery origin, can be a major concern. Wild fall chum salmon are currently very abundant in Hood Canal streams, and although they do not directly compete with summer chum salmon for spawning sites because of temporal separation, the construction of redds by fall chum could potentially cause the loss of previously deposited summer chum eggs and alevins because of redd disturbance.

The large magnitude of the hatchery fall chum salmon program in Hood Canal has raised concerns about the potential impact on summer chum salmon (WDFW and WWTIT 1994, Johnson et al. 1997). The combined numbers of wild and hatchery produced chum fry entering Hood Canal in recent years likely exceeds past historic, wild-only juvenile population levels. Both the numbers and timing of releases suggest that there may be possible negative competitive impacts on summer chum salmon stocks. Hatchery programs for other species of salmonids have in some cases been intense, and the potential for both competitive and predatory impacts on summer chum salmon juveniles has been identified (WDFW et al. 1993, Johnson et al. 1997, Tynan 1998).

Beginning with the 1992 brood, summer chum salmon supplementation programs were initiated at the USFWS hatchery on the Big Quilcene River and by Wild Olympic Salmon on Salmon Creek. Since summer chum salmon have not been artificially propagated in the Hood Canal or Strait of Juan de Fuca regions during the 1970s and 1980s, hatchery propagated summer chum could not have contributed to the recent decline of the wild populations.

The following section reviews existing information on the possible effects of competition and predation on Hood Canal and Strait of Juan de Fuca summer chum salmon populations. Various wild and hatchery salmonids, marine fish, birds, and marine mammals are discussed.

2.2.3.1 Wild Fall Chum Salmon

> **Fall Chum Salmon**
>
> ***Stocks of chum salmon that return from October through December, and spawn from November to January in Hood Canal streams. Fall chum stocks are genetically distinct from summer chum salmon.***

Fall chum salmon populations are present in each of the Hood Canal streams currently supporting summer chum salmon. Of the streams used by summer chum salmon in the eastern Strait of Juan de Fuca, only the Dungeness River also has a fall chum salmon population. In Hood Canal, the differences in timing between the summer and fall chum adult return and spawning periods precludes direct interactions in the spawning streams between adults of the two run timings (WDFW and WWTIT 1994). The later spawning fall fish, however, could cause negative impacts on summer chum salmon, by physically disrupting their redds and increasing the mortality of the incubating eggs and alevins.

Hood Canal fall chum salmon generally spawn farther upstream than summer chum salmon, but, there is overlap of spawning grounds in all streams. In the case of streams with migration barriers the degree of overlap can be extensive. The much higher stream flows that are typical of the November-January spawning period of fall chum can result in the selection of individual spawning locations away from the low water, mid-channel, redd sites of summer chum salmon. As stream flows increase, preferred spawning depths and velocities occur nearer to the shoreline, and spawners tend to select spawning sites closer to the margins of the stream, away from center channel (Ames and Beecher 1995). This type of partitioning of spawning riffles can moderate the effects of redd superimposition, and may in part explain how summer and fall spawning chum salmon can coexist in the same stream. Another factor mitigating the impacts of the disturbance of summer chum redds, is that the eggs of summer chum salmon should have developed to the eyed stage by the time that native fall chum arrive to spawn, and should be able to physiologically tolerate a modest amount of shifting and movement caused by redd superimposition.

Another type of potential competition between the two forms of chum salmon would occur during the juvenile estuarine and inshore marine waters feeding and growth phases. It has been suggested that artificially produced fall chum salmon may pose an ecological risk to summer chum salmon because of increased competition for food resources (Johnson et al. 1997). Wild fall chum salmon could potentially have an impact if sizeable populations have substantial temporal and spacial overlaps with summer chum salmon in estuarine or inshore marine waters. This is not the case, however, since there are distinct temporal variations in the early life histories of the summer chum and wild fall chum stocks in this region.

For wild fall chum salmon to have contributed significantly to the observed decline of Hood Canal summer chum salmon, either as adult or juvenile competitors, a major increase in population size over pre-decline levels would be necessary. Table 2.6 presents the 1974-1997 escapements of Hood Canal summer and fall chum salmon in common streams summarized as five-year averages (more detailed descriptions are provided in Table 1.2 and Appendix Table 1.1). For the 1974-1978 periods, average escapements to common streams, are similar for both chum salmon forms, but during the 1979-1983 years both summer and fall chum escapements have dropped precipitously. Fall chum bottom out with a low escapement of 2,766 spawners to summer chum streams in 1983, and then begin to display an increasing trend (Appendix Table 2.3). During the most recent five years, escapements of fall chum have averaged over 88,000 spawners. The similar performance of the two forms of chum salmon, in terms of escapements, during the periods immediately before and after the summer chum salmon decline does not suggest a major change in the potential interactions between the summer and fall fish. The large 1994-1998 increase in fall chum escapements that has occurred in concert with the improved summer chum escapements during the same years also suggests that competition between wild summer and fall fish is not a significant limiting factor. It is likely that the differences in life history timing are sufficient to allow the two forms to coexist in the freshwater and marine environments (see discussion of timing differences in the Hatchery Fall Chum section below).

Table 2.6. Five year average escapements of Hood Canal summer and fall chum salmon to those streams with summer chum populations (1974-1998).

Return years	Summer chum escapements	Fall chum escapements
1974-78	17,773	20,006
1979-83	3,238	5,257
1984-88	1,760	16,919
1989-93	978	29,816
1994-98	9,078	88,599

The abundant fall chum may have an unique positive interaction with summer chum salmon, by helping to stabilize stream beds and minimize flood effects on summer chum salmon. In a study of chum salmon spawning in Kennedy Creek (south Puget Sound), Montgomery et al. (1996) has found that the sorting of stream gravels by mass spawning of chum salmon stabilizes the stream-bed, which leads to a reduced probability of erosion during subsequent high flow events and reduces the loss of chum salmon eggs and alevins. These authors also point out that the feedback system between mass spawning and streambed stability can be interrupted by a declining spawner population trend, adding to the difficultly of recovering a depressed salmon stock. In the case of Hood Canal summer chum salmon, it may be that the abundant mass-spawning fall chum salmon are contributing to stream-bed stability conditions, benefitting both summer and fall populations.

2.2.3.2 Hatchery Fall Chum

The artificial propagation of fall chum salmon at hatcheries in the Hood Canal region over the last 20 years has been very successful, producing adult returns numbering from 100,000 to over 600,000 fish each year (Tynan 1998). The large returns result from chum salmon propagation programs at five hatcheries that release juveniles into the waters of Hood Canal (two WDFW hatcheries, one USFWS hatchery, and two tribal hatcheries). In addition to the formal hatchery programs, numerous Volunteer Enhancement Program remote site incubators (RSI) release unfed fry into a number of Hood Canal streams.

As reported by Johnson et al. (1997), the artificial propagation of chum salmon began in 1905 at a state hatchery in the Skokomish system, and expanded in 1911 and 1912 at USFWS hatcheries on the Duckabush and Big Quilcene rivers. The USFWS program originally included both summer and fall chum salmon, however, summer chum production was dropped at the two stations after 1937 at Big Quilcene and after 1942 at Duckabush (Cook-Tabor 1994). The Hoodsport fall chum salmon program began in 1953, when the hatchery facility first became operational, and has been built solely from native Finch Creek fish (Tynan 1998). In 1976, George Adams and McKernan hatcheries (WDFW) began to release fall chum salmon (Finch Creek stock) into the Skokomish system. In 1977, Enetai Hatchery (Skokomish Tribe) began to release Quilcene stock fall chum salmon into a small independent stream located just north of the mouth of the Skokomish River. That same year, the Port Gamble Hatchery (Port Gamble S'Klallam Tribe) initiated releases of Quilcene stock fall chum but switched to Finch Creek stock by 1979.

The WDFW Hoodsport Hatchery on Finch Creek has been the largest fall chum salmon program in Hood Canal over the last three decades. During the early years, the hatchery's goal was to take enough chum eggs to keep a maintenance run at the station, however, in 1968 the objectives changed to take as many eggs as possible (Schwab 1974). Current goals for the WDFW Hood Canal fall chum salmon hatchery program are to enhance tribal and all-citizen commercial fisheries, enhance a local Hoodsport vicinity recreational fishery, and provide eggs in support of the Skokomish system hatcheries and Volunteer Enhancement Program cooperative projects (Tynan 1998).

Annual egg take goals, as specified in the 1986 Hood Canal Salmon Management Plan, are for sufficient eggs for the release of 40 million fry (subsequently reduced to approximately 36 million fry), plus additional eggs (if available) to support the operations of local enhancement groups. The annual releases of all Hood Canal WDFW hatchery produced fall chum salmon (1969-1993 brood years) range from a low of approximately 984,000 fish for 1969 brood to a high of 50,330,000 fish from the 1984 brood, and average 24,042,000 fish over the entire period (see Appendix Table 2.4). An average of approximately 5 million additional juvenile chum salmon are released from the tribal and federal hatcheries (Johnson et al. 1997), and the Volunteer Enhancement Program has released of an average of 5.25 million fish between 1990 and 1994 (Tynan 1998). In total, these large numbers have generated concerns that the fall chum salmon hatchery program in Hood Canal could have a potentially negative competitive impact on summer chum salmon (WDFW and WWTIT 1994, Johnson et al. 1997).

There is a general correlation between the increasing hatchery fall chum salmon program and the decline in summer chum salmon. The 1975 and 1976 brood years of Hood Canal summer chum salmon declined abruptly in abundance, as evidenced by adult escapements in 1979. The WDFW hatchery fall chum salmon program expanded substantially in the early-1970s, increasing from a 1972 brood release of 1.0 million, to 3.4 million for the 1973 brood, and 9.4 million for the 1974 brood (Table 2.7). Another major production jump occurred with the release of 29.6 million 1978 brood fall chum salmon.

While these expansions of hatchery fall chum releases have occurred during the general time frame of the summer chum collapse, they are out of synchronization by several years. The increased hatchery releases of 1973 and 1974 broods should have directly impacted the returns of age-3 and age-4 summer chum salmon in 1976, 1977, and 1978, and the 1978 hatchery increase should have affected the 1981 and subsequent broods (Table 2.7). The 1979 summer chum salmon decline falls between these two periods of change in hatchery fish abundance. One possible explanation for this lack of direct synchrony is that it may have taken two years of increased hatchery releases to depress invertebrate prey abundance to the point that summer chum salmon juveniles were affected. If this scenario actually occurred, the 1974 brood releases of 9.4 million fall chum salmon would have over-cropped invertebrate prey resources in the canal, contributing to lowered prey reproduction the following spring, and reduced production of food resources for the competing 1975 brood hatchery fall (8.5 million release) and wild summer chum juveniles.

Countering the theory of hatchery fall chum salmon competitive impacts is survival data for Hoodsport Hatchery fall chum salmon showing that both the 1974 and 1975 broods experienced above average marine survivals. If food resources had become limiting to the point of causing the observed decline in 1975 brood summer chum salmon, the hatchery fish should have displayed a corresponding drop in survival. Another argument that counters the general negative correlation between hatchery fall chum releases and summer chum salmon status is that the returns of summer chum salmon have increased substantially in recent years, with roughly four times as many hatchery chum released into Hood Canal as was the case in the mid-1970s (Table 2.7).

Since the hatchery and summer chum discussion above does not clearly resolve the issue of the possible contribution of the hatchery fall chum program to the summer chum salmon decline, the following section will review the available research on the ecological relationships of chum salmon in Hood Canal.

Juvenile chum salmon in the Hood Canal estuary - A considerable body of scientific literature exists on the subject of the ecological relationships of chum salmon in Hood Canal. Nearly all of these studies have been conducted by researchers from the University of Washington, in part to determine the potential impacts of the construction and operation of the Bangor Naval Base. While these studies are not always able to specifically look at differences between summer and fall chum salmon, they do offer a broad picture of juvenile chum salmon life history in Hood Canal.

Table 2.7. Total brood year releases of WDFW hatchery fall chum to the waters of Hood Canal, and return years as age-3 and age-4 adults (1969-1998 broods).

Brood year	Total releases	Return years (age 3 & 4 fish)
1969	938,788	1972, 1973
1970	1,447,406	1973, 1974
1971	1,363,110	1974, 1975
1972	1,039,168	1975, 1976
1973	3,374,966	1976, 1977
1974	9,408,285	1977, 1978
1975	8,465,125	1978, 1979
1976	13,679,756	1979, 1980
1977	7,939,467	1980, 1981
1978	29,606,329	1981, 1982
1979	39,110,094	1982, 1983
1980	36,340,223	1983, 1984
1981	16,859,884	1984, 1985
1982	35,905,744	1985, 1986
1983	28,325,669	1986, 1987
1984	50,330,002	1987, 1988
1985	36,535,000	1988, 1989
1986	40,400,100	1989, 1990
1987	40,122,500	1990, 1991
1988	35,217,100	1991, 1992
1989	34,521,500	1992, 1993
1990	19,619,100	1993, 1994
1991	38,639,100	1994, 1995
1992	39,652,200	1995, 1996
1993	33,205,650	1996, 1997
1994	37,860,000	1997, 1998
1995	34,324,091	1998, 1999
1996	34,508,783	1999, 2000
1997	25,388,986	2000, 2001
1998	24,344,935	2001, 2002

The following quotations are from a WDFW discussion of the subject (Crawford 1997).

Spatial overlap or separation during migration - Historical release strategies (fed vs. unfed fry) and release sizes (size range from swim-up to 1.2 gm) during the pre-April 1 time period (see Appendix Table 2.4) are important factors to adequately assess the likelihood for the co-occurrence, and hence competition, of hatchery fall chum and summer chum in the Canal.

"Schreiner (1977) reported that migrating chum fry in Hood Canal remained in near-shore areas until reaching a length of 45-50 mm, when the chum were observed to move to deeper off-shore areas. Other authors also reported that chum released from Hood Canal hatcheries at or near this size range early in the season tended to migrate rapidly northward and into offshore areas (Whitmus and Olsen 1979; Prinslow et al. 1979; Prinslow et al. 1980; Salo et al. 1980; Bax and Whitmus 1981; Whitmus 1985). A 45 mm chum weighs 0.73 grams (or 622 fpp), which is comparable to the 0.66 gram (686 fpp) average size of fed fall chum released prior to April 1 from the Hood Canal hatcheries (Table I). Bax (1983) observed that wild chum migrating prior to April showed little change in length as time progressed, averaging 35-44 mm in fork length (Schreiner 1977; Bax et al. 1978). The best scientific information would suggest that fed fall chum fry of the average size released from Hood Canal hatcheries pre April 1 do not share the same feeding and/or migratory areas as summer chum. Unfed fry groups released from the hatchery facilities prior to April 1 have a greater likelihood for interaction with summer chum, as they are of similar, if not the same size, and likely use the same nearshore areas for foraging during migration."

Food item overlap during migration - The differences in types of prey that are predominantly taken by chum fry of differing sizes (and foraging in differing areas) must be considered to adequately assess the potential for competition between hatchery fall chum and wild summer chum.

"Bax et al. (1978) and Simenstad et al. (1980) reported that immediately upon entry into Hood Canal small (30-40 mm fl) juvenile chum fry (of naturally-producing populations or from the Big Beef Creek spawning channel) captured in nearshore areas during out- migration in Hood Canal fed primarily on epibenthic organisms, mainly harpacticoid copepods, gammarid amphipods, polychaete annelids, and crustacean eggs. After the fish grew larger than 45-55 mm fl (or entered the Canal at this size from hatchery facilities) and moved to off-shore areas, they fed mainly upon pelagic organisms, such as euphausids, calanoid copepods, and hyperiid amphipods. Simenstad et al. (1980) also reported on the effect of fish size upon selection of foraging habitat by illustrating comparative prey spectra of chum fry captured via beach seine in shallow sublittoral habitats with the prey spectra of tow-net caught chum (recognizing that the size of chum increases with increasing distance from shore). Larvaceans and harpacticoids comprised over 60 % of the total prey spectrum of chum captured in nearshore areas, whereas over 85 % of chum captured off-shore was euphausids, calanoid copepods, and hyperiid amphipods (Simenstad et al. 1980). The best scientific information would suggest that fed fall chum fry of the average size released from Hood Canal hatcheries before April 1 and wild summer chum have a low likelihood of diet overlap during migration."

Rapid out-migration during February-March time period - The tendency of juvenile chum entering the Canal before April 1 to outmigrate rapidly should be considered in any assessment of the likelihood for resource competition.

"As reported in Simenstad et al (1980), chum fry entering the Canal early in the outmigration period (February-March - the summer chum fry migratory period) generally encounter a naturally low abundance of prey resources, and rapid outmigration may be one behavioral response to this low availability. Salo et al (1980), Prinslow et al. (1980), Bax (1982), and Bax (1983) all report rapid out- migration and short residence time for juvenile chum in the Canal during this time period. The fact that chum entering the estuary during February and March migrate out of the Canal quickly does not lend well to an argument for resource competition between summer chum and hatchery-origin fall chum. The likelihood is that the duration of interaction between these groups is minimal."

Timing of fall chum releases - Prior to the late 1970s, the releases of fed (reared) fall chum fry for Hood Canal hatcheries all have occurred after April 1 (Appendix Table 2.4), with average release dates in the first week of May (Tynan 1998). This release schedule has provided substantial separation between summer and hatchery fall chum juveniles; with the summer fish having a peak Hood Canal exodus timing of April 1- April 3, and completing emigration from the canal around the first of May (Tynan 1997). In 1992 and 1993, pre-April hatchery chum fry releases into Hood Canal total 19.7 million and 28.6 million fish respectively (Appendix Table 2.4 - note that release year is the year following brood year shown in table).

Again, the following quotations are from Crawford (1997):

"The primary annual production objective of fall chum hatcheries in Hood Canal is the release of one gram fed fry after 30 to 60 days of rearing (50 mm average fl, or 450 fpp) in April or May. Chum released at this size have been shown to have higher survival rates to adult return in Hood Canal (H. Fuss, WDFW personal communication 4/1/97). The April-May release timing of these fish into Hood Canal coincides with the emergence and marine out-migration timing of wild fall-run chum, which enter seawater at a smaller size (0.37 gram avg. (Koski 1975), or 35-40 mm avg. fl (Schreiner 1977)). During years of good hatchery growth (warm rearing water, good husbandry practices), or in years when hatchery pond space used for fall chum was limiting, fed fall chum have been released earlier than April. Out of an average total fall chum fed fry release from WDFW hatcheries in Hood Canal of 20,899,836 (1970-94 data, range of 795,040 - 45,955,845), an average of 6,125,158 (range 0 - 20,073,200) or 29.3 % of the total annual production (range 0 % - 64.9 %) have been released prior to April 1. These pre-April 1 release fed fry have ranged in size from 0.36 to 1.2 grams (39 - 54 mm fl) and have averaged 0.66 grams (44 mm fl) between 1970 and 1994.

Hood Canal hatchery facilities also have produced unfed fall chum fry. These fish have generally been produced in remote site incubators, and released without any rearing at a size of 0.34 to 0.38 grams (35-40 mm) upon swim-up. On average, 49.2 % (1970-94 data, range 0 % - 100 % of the unfed fry groups have been released in February or March. Annual unfed fry releases in Hood Canal have averaged 3,142,224 (range 0 - 8,744,000), with 1,545,856 (range 0 - 8,494,000) of the total released prior to April 1 on average.

In the NMFS document "Review of Information on Hood Canal Summer Chum Salmon ESU collected in 1995 and 1996", it is noted that 1992 brood year summer chum returns to the western tributaries and Quilcene Bay were very strong, exhibiting some of the highest apparent recruit per spawner rates that have been documented for Puget Sound chum. As discussed above, hatchery release data for 1992 brood fall chum indicate that over 20,000,000 fed fry and over 8,400,000 unfed fry were released from Hood Canal hatcheries prior to April 1, 1993, coincident with the out-migration of this extremely successful 1992 summer chum brood. The pre-April 1 fall chum liberations that year were 3.3 times greater than 1970-94 average fed fry levels and 5.5 times greater than 1970-94 average unfed fry release levels. Collectively, the pre-April 1 fall chum fed and unfed fry releases coincident with the migration period of 1992 brood summer chum in 1993 were the largest on record (see attached Appendix Table 2.4).

The fact that 1992 brood wild summer chum exhibited such high survival in the midst of the largest pre-April 1 fall chum hatchery releases into Hood Canal on record does not support an argument for negative impacts of competition between wild summer chum and hatchery fall chum during this time period. Based upon the performance of the 1992 brood summer chum, we could in turn speculate that the magnitude of pre-April 1 hatchery fall chum releases in 1993 effectively minimized the effects of predation on commingled 1992 brood wild summer chum by swamping potential predators with alternative prey."

Remote site incubators - Enhancement of chum salmon using remote site incubators (RSI) has occurred within the region, with 17 sites identified on Hood Canal and Strait of Juan de Fuca streams by Johnson et al. (1997). Summer chum have not generally been included in the RSI program; the exceptions being the recovery projects at Salmon Creek, Lilliwaup, and Hamma Hamma, and the efforts to reintroduce summer chum salmon to Chimacum and Big Beef creeks.

The RSI program began to release substantial numbers of fall chum salmon unfed fry into Hood Canal streams in 1978. For brood years 1978 through 1993, an average of just under 5 million (range 0 - 8.7 million) fall chum unfed fry were released annually from all facilities, including RSIs (Appendix Table 2.4). While the RSI releases have not been totaled separately, they make up approximately 6% of the overall unfed fry released annually. Not all of the RSI release sites are on summer chum salmon streams. For example, in review of fall chum salmon RSIs on the streams of west Kitsap Peninsula, only half of the projects are located on summer chum salmon streams (Turner 1995). The first major releases occurred in 1978 (adults returning in 1981-1983), which does not match with the summer chum decline beginning with the 1975 and 1976 broods.

The numbers of unfed fry released are small when compared to the tens of millions of fed chum fry produced in Hood Canal hatcheries. It is unlikely that the RSI program have contributed to the observed decline of summer chum salmon, because of the relatively small release numbers, and because the inception of the program is several years out of synchronization with the decline.

Conclusions - The recent success of summer chum, in the face of very large hatchery releases of fall chum, suggests that competitive interactions have not been a significant contributor to the decline of summer chum salmon. Additionally, the lack of direct synchrony between hatchery releases and changes in summer chum abundance, and the ecological differences between summer and fall chum in marine waters, support the likelihood of minimal interactions. A possibility that must be considered is that the apparent negative correlation between hatchery fall chum salmon and the decline of summer chum salmon may simply be a coincidence. There is still uncertainty surrounding the issue of juvenile fall and summer chum interaction, and further investigation may be warranted.

2.2.3.3 Other Salmonids

Summer chum salmon share spawning streams, estuaries, and nearshore marine waters with a number of other salmonids in addition to fall chum salmon. These other salmonids include wild and hatchery origin chinook, coho, and pink salmon, and steelhead and cutthroat trout. The wild populations of these species have not increased during the periods of summer chum salmon decline (pink salmon excepted), and it is unlikely that they have contributed substantially to the observed changes in summer chum status. However, there has been a general concern expressed about the possible effects of outplanting of hatchery chinook, coho, and trout in summer chum streams (WDFW and WWTIT 1994, Johnson et al. 1997, Tynan 1998). There are several levels of concern; adult competition for spawning sites, juvenile competition for food, and predation on juvenile summer chum.

There have been several investigations into the interaction between salmonid species in the region (Schreiner et al. 1977; Simenstad and Kinney 1978; Prinslow et al. 1980; Bax et al. 1980; Simenstad et al. 1980; Whitmus 1985 among others). Based on studies in Hood Canal, Simenstad and Kinney (1978) and Prinslow et al. (1980) conclude that predation on chum salmon by other species, including salmonids, in the open waters of Hood Canal is insignificant. However, a number of authors studying early marine migration behavior for chum in Hood Canal report significant, high mortality levels during the first few days of residence in the estuary that may be caused by predation.

Fluorescent pigment-marked chum salmon released from Big Beef Creek during February in 1978 and 1979 had mortality rates of 29 % and 49 % of the population, respectively, during the first two days in the estuary (Salo et al. 1980). Prinslow et al. (1980) reported a survival rate of 44 % (mortality rate of 56 %) for the 1978 brood chum migrating from Big Beef Creek after four days. Whitmus (1985) documented a mortality rate of 58 % and 74 % over 2 days for 45 mm chum fry released in two groups during early

May from Enetai Hatchery in Hood Canal. Bax (1983a) reported average daily mortality rates for Enetai fall chum of between 31 % and 46 % over a two and a four day period. Predation by cutthroat trout and marine birds was thought to account for the mortality of chum juveniles released from Enetai (Whitmus 1985), and Bax (1983) hypothesized that high susceptibility to predation and attraction of predators to the chum fry release location were responsible for high mortality rates estimated in his study.

Considerable uncertainty exists regarding the adverse effects of species released in regional hatcheries on chum salmon through competition. Chum and pink salmon have been shown to use the same nearshore beach environment during their initial period of residence and prey upon the same sublittoral epibenthic crustacean populations during emigration (Schreiner et al. 1977). Ames (1983) has conducted a preliminary examination of the interactions between the salmon species in Hood Canal, and has identified only pink and chinook salmon as possibly having a negative impact on chum salmon survivals. This is a limited study that examines only short-term data sets from before 1979, and does not include the trout species.

The following discussion will consider the general interactions known to occur between the various species. The risks to summer chum of hatchery programs producing other salmonid species in the region are assessed in a separate section of this plan (3.3 <u>Ecological Interactions</u>). The following text summarizes information more fully detailed in section 3.3 regarding hazards, interactions, and potential effects to summer chum that may result from the hatchery production of chinook, coho, and pink salmon, and trout species within the Hood Canal and Strait of Juan de Fuca regions.

Summer chum juvenile timing - The potential impacts on summer chum salmon associated with the releases of hatchery origin salmonids are largely controlled by the degree of overlap in the timing of releases compared to the timing of juvenile chum life history stages. Many releases of hatchery fish are timed to avoid significant interactions with sensitive species.

The critical survival periods for summer chum salmon are the incubation, emergence and emigration stage in freshwater, and the early marine emigration period. Tynan (1997) has summarized, and estimated from available field studies, juvenile timing of Hood Canal and Strait of Juan de Fuca summer chum salmon, and the following information is taken from that assessment. The ranges of dates presented below represent the earliest beginning date and latest ending date observed (or estimated), and chum of a particular life stage would not necessarily be present through the full range of these dates every year (see Tynan 1997). Summer chum eggs are estimated to be present in the “tender stage” in stream gravels from early September through early November in an average year. This period can be viewed as the time when summer chum eggs are most vulnerable to disturbance during incubation. Estimated emergence timing for Hood Canal summer chum salmon ranges from February 7 to April 14, with an average peak of March 18 for east side stocks, and March 27 for westside stocks. For Strait of Juan de Fuca stocks, the emergence timing ranges from February 15 to May 26, with a April 5 average date for the peak. Since nearly all chum salmon fry emigrate to sea immediately following emergence from the gravel, the same dates represent both emergence and emigration. Estimated summer chum salmon juvenile departure dates from Hood Canal range from February 21 to April 28, with an April 2 average peak date. Strait of Juan de Fuca summer chum are estimated to be present in inshore waters ranging from February 28 to June 8, with an April 17 average peak.

Steelhead and cutthroat trout - Because of major differences in the life histories of chum salmon and the trout species, substantial juvenile and adult competition between chum salmon and trout is unlikely. It is known, however, that sea-run cutthroat trout are predators on juvenile salmonids in the marine environment (Simenstad and Kinney 1978; Cardwell and Fresh 1979; Whitmus 1985). Steelhead trout released as yearling smolts during the summer chum emigration period are also viewed as posing a high predation risk in the freshwater and marine environments due to their large size relative to the chum fry (Fresh et al. 1984).

Most summer chum streams in the region have received steelhead out-plants within the past thirty years, and during the period of decline for summer chum in Hood Canal (Tynan 1998). The number of steelhead smolts planted has been reduced in recent years, from a 1965-98 average of 94,000 in Hood Canal to under 80,000 (1995-1998 release levels) (Appendix Figure 2.9). Steelhead releases in the Strait of Juan de Fuca region have been similarly reduced, to about 13,000 from a 1955-97 average of 19,000 (Appendix Figure 2.10). Also, steelhead are now released into only four watersheds within the Hood Canal and Strait of Juan de Fuca region: Skokomish River, Dosewallips River, Hamma Hamma River, and the Dungeness River. In Hood Canal streams, the normal release size for steelhead smolts has been 4-7 fish per pound (fpp) or 180 - 230 mm and this large size at release makes this species a potential predator on newly emerged chum salmon fry (Tynan 1998). The release of only smolts in the steelhead hatchery program enhances their tendency to immediately migrate to marine waters, which may extend the period of potential predation on chum salmon fry into the nearshore marine areas. Steelhead released in Strait of Juan de Fuca streams are of a similar size (3-6 fpp).

Sea-run cutthroat trout were released into several Hood Canal summer chum streams from the mid-1980s through the early 1990s, but, commencing in 1992, are no longer released into anadromous areas within the region (Appendix Figure 2.9). No streams in the Strait of Juan de Fuca region have been planted with sea-run cutthroat within the past 42 years (Tynan 1998). In previous years, an annual (1985-91) average of 27,000 sea-run cutthroat were released into Hood Canal streams at a size of 4-16 fpp (128-230 mm). The piscivorous nature of the species and the large size at release relative to emigrating summer chum elevates the likelihood that the species preyed on emigrating chum, including summer chum. Several studies in Hood Canal document predation on chum salmon fry by sea-run cutthroat (Simenstad and Kinney 1978; Prinslow et al. 1980; Whitmus 1985).

The cessation of all hatchery sea-run cutthroat releases into anadromous waters within the region eliminates the need to consider their predation effects on summer chum. In large part the potential for hatchery steelhead predation on chum fry is mitigated by timing of releases. Steelhead smolt releases occur in April and May in both Hood Canal and the Strait of Juan de Fuca (Tynan 1998). In some years, when summer chum fry emergence extends until mid-April, steelhead smolts are released in summer chum streams while chum fry are still present. Additionally, these steelhead releases can have access to summer chum fry in marine waters until the end of April.

Chinook and coho salmon - Annual fall chinook salmon smolt releases from Hood Canal region hatcheries have averaged 6.1 million sub-yearlings and 226,000 yearlings since 1990 (Appendix Figure 2.11). Releases of this species into Hood Canal were quite low during the late 1970 period of summer chum decline relative to late 1980 levels. Chinook smolt out-plants in the region have declined significantly since 1989. Strait of Juan de Fuca region chinook production was low to non-existent between 1974 and

1994. Recent year chinook releases into summer chum streams (the Dungeness River) have been 975,000 sub-yearlings, 200,000 fingerlings, and 800,000 fed fry Appendix Figure 2.12). Appendix Figures 2.13 and 2.14 present annual coho salmon juvenile release levels into the same summer chum regions. Annual coho juvenile release levels have remained quite stable across the last twenty years, with the exception of unfed fry releases, which were discontinued in the early 1990s.

Hatchery-origin chinook and coho salmon smolts are thought to pose a high risk of a significant negative impact on wild chum salmon due to predation in freshwater and nearshore estuarine areas where the species co-occur (Fresh et al. 1984). Coho salmon are of special concern for predation effects due to their large size at release as yearling smolts (average release size 10 - 17 fpp, or 130 - 160 mm) relative to the size of emigrating wild summer chum (1,000 - 1,200 fpp, or 35-39 mm) (Tynan 1998). Most chinook salmon are released from hatcheries as sub-yearlings, averaging 65-80 fpp, or 80 - 86 mm), making predation on emigrating chum salmon unlikely. Yearling chinook salmon released from net-pens in Hood Canal at an average size of 5 fpp (195 mm) likely pose a predation risk to summer chum fry if present in estuarine areas during the summer chum emigration period.

Extensive stomach content analysis of coho and chinook salmon smolts in Hood Canal show only minimal evidence of predation on other salmonids, including chum salmon (Simenstad and Kinney 1978; Whitmus 1985). Although these species were captured in the same seine sets during the predation studies, they may not have been occupying the same area, leading to the observations of no predation by coho and chinook smolts (Whitmus 1985). Visual observations prior to seining in the Whitmus (1985) study indicate a potential for horizontal segregation of chum and coho smolts when coho are very abundant in areas where chum are also present.

Due to a freshwater entry timing similar to summer chum, non-indigenous-origin fall chinook adults planted in, or straying into, summer chum streams may compete for spawning sites, and may disrupt summer chum survival through redd superimposition. Although there are no direct studies to evaluate actual effects on summer chum productivity, hatchery-origin fall chinook have been routinely observed spawning in the same areas used by indigenous summer chum populations (R. Egan, WDFW, pers. comm., August 1999).

Like hatchery steelhead releases, the risk of predation by hatchery-origin chinook and coho salmon yearling smolts is largely mitigated by the late timing of yearling and sub-yearling releases from regional hatchery facilities relative to the estimated summer chum emigration period. Yearling sub-yearling chinook salmon smolt releases occur in early May and early June respectively in Hood Canal, where all of the fall chinook within the summer chum region are produced. Dungeness native-origin chinook sub-yearling smolts are released into Strait of Juan de Fuca waters between mid-June and mid-July, a period well past the March-April summer chum fry emigration (Tynan 1998). The risk of competition posed by fall chinook on the spawning grounds can be minimized by discontinuance of fall chinook releases that are not part of a formal recovery program into summer chum streams.

Pink salmon - The Dosewallips, Duckabush, and Hamma Hamma rivers support separate stocks of pink salmon, and limited numbers of this species are occasionally observed in the Big Quilcene River and Lilliwaup Creek. Pink salmon spawn in these streams (odd-years only) in September and October; the same spawning period as summer chum salmon. Potential interactions between the two species would include competition by adults for spawning sites, redd superimposition, and competition for food resources in the estuary and marine waters. Since pink salmon are only present every other year, any significant negative impact on summer chum salmon should result in a biennial pattern in the survival and return rates of summer chum. The ecological similarities in the life histories of pink and chum salmon do result in lower returns of chum salmon in dominant pink return years throughout the range of the two species (odd-years for southern populations and even-years in northern areas). Competition between juveniles in marine waters is the most likely explanation for this effect (Gallagher 1979, Ames 1983, Salo 1991). For local summer chum salmon stocks, however, there is no obvious short-term cyclic effect in the years following the 1979 summer chum decline, i.e. no changes in the return rates of just the odd-year chum salmon brood years. To the contrary, Hood Canal summer chum salmon are currently the most successful in streams that they co-habit with pink salmon, which argues against a substantial change in the competitive interactions between these species.

There is an artificial propagation program for pink salmon at the WDFW Hoodsport Hatchery that has operated since 1953. This program has released an average of approximately 1.5 million pink fry per year (Tynan 1998) (Appendix Figure 2.15). There is no indication that these releases have contributed to the summer chum decline. However, to minimize the likelihood for adverse effects, attempts are being made to minimize interactions between hatchery pink salmon releases and summer chum by delaying pink salmon releases until after April 1.

Current Hatchery Programs - As addressed in the previous section, the hatchery-induced hazard that has had the highest potential to have negatively affected summer chum is competition in the estuary posed by fall chum salmon released during the summer chum emigration period. Although no adverse effects on summer chum survival resulting from past early liberations of fall chum are readily evident, it is possible that fall chum compete for limited food resources available in Hood Canal during their early spring migration.

Although steelhead smolts are currently truck-planted into several summer chum streams within the region, the late planting date of the fish relative to the summer chum emigration period likely prevents interaction between the two species, and adverse effects. Due to their piscivorous nature and continuous presence in nearshore estuarine areas, past production of sea-run cutthroat may have had negative predation effects on summer chum. The cutthroat program has been discontinued and adverse effects posed to summer chum are therefore no longer a concern.

Releases of fall chinook and coho salmon smolts, as presently practiced in the region, are judged to not pose risks of predation to summer chum. These two species are released from regional hatcheries much later than the summer chum emigration period, reducing the likelihood for interaction. Extensive stomach content analyses of coho salmon smolts collected during University of Washington Fisheries Research Institute studies in Hood Canal, as well as those in northern Puget Sound, the Strait of Juan de Fuca, and Nisqually Reach do not substantiate any indication of significant predation upon juvenile salmonids in Puget Sound marine waters (Simenstad and Kinney 1978). Similarly, Hood Canal, Nisqually Reach, and north Puget Sound data show little or no evidence of predation on juvenile salmonids by juvenile and immature chinook (Simenstad and Kinney 1978). Although available studies indicate that predation on juvenile salmonids, including summer chum fry, is not of great concern, release practices that ensure spatial and temporal separation between hatchery fall chinook and coho and summer chum should be continued.

Further studies are needed in nearshore areas to fully evaluate the risk of predation to summer chum emigrants posed by resident chinook and coho resulting from the Hood Canal hatchery programs.

Pink salmon released from Hoodsport Hatchery in March may pose risks to summer chum fry through competition for food resources. Risks of adverse competitive effects posed by hatchery pink salmon are proposed to be addressed by delaying releases of these species until after the summer chum emigration period (post April 1). This practice may reduce the likelihood for interactions between the two species, minimizing the risk of food resource competition. However, it is unclear if this measure can be practically met due to the early timing of pink egg takes and emergence periods in the hatchery, which makes holding pink salmon through April 1 problematic. Also, benefits to emigrating summer chum afforded by "swamping" of predator populations by hatchery pink releases will be forgone with this practice.

Conclusions - While there are uncertainties about the effects of competition and predation by salmonids on summer chum salmon, because of the magnitude of hatchery releases during the 1970s and early 1980s these types of interactions likely have contributed to the decline of the summer chum stocks of Hood Canal. There is a low likelihood that Strait of Juan de Fuca summer chum stocks have been affected by releases of hatchery salmonids.

2.2.3.4 Marine Fish

Most marine fish species that inhabit the same waters as chum salmon are potential predators and/or competitors, particularly during juvenile chum salmon life stages. However, diet studies have shown that other salmonids are usually the principal predator/competitor species affecting chum salmon (Bakkala 1970, Emmett et al. 1991).

The status of bottom fish species in Hood Canal and the Strait of Juan de Fuca has been the subject of two separate WDFW stock status inventories; for bottomfish (Day et al. 1995), and for forage fish (Lemberg et al. 1997). These inventories tracked trends in marine fish populations using catch and effort statistics from recreational and commercial catches.

Most bottomfish species in the region have declined over the last three decades, possibly influenced by some of the same climate changes that have affected chum salmon. Catches of several species briefly increased in the late 1970s (e.g., dogfish and lingcod), however, this was due to higher exploitation rates in trawl fisheries and was not the result of increased abundance (Greg Bargmann, WDFW, pers. comm.).

The forage fish species are predominately represented by Pacific herring in the marine waters of the region. Herring assessment surveys have been conducted in multiple index areas in both Hood Canal and the Strait of Juan de Fuca since 1977, and show either stable (Hood Canal) or declining (Strait of Juan de Fuca) trends in abundance. The initiation of these surveys coincides with the PDO regime shift, and there are no quantitative data from earlier years to indicate if herring abundance changed at that time. Anecdotal information suggests that regional herring populations have had similar abundances before and after the 1977 climate change (Greg Bargmann, WDFW, pers. comm.).

As pointed out above, the various local marine fish species are potential summer chum competitors and/or predators. However, based the abundance trends of these species over the past two decades, it is unlikely that extraordinary levels of predation or competition by bottom fish or herring have been a significant factor in the observed decline of summer chum salmon in Hood Canal or the Strait of Juan de Fuca.

2.2.3.5 Birds

Common Mergansers are well-known to feed on juvenile salmon during their downstream migration and could be taking summer chum fry. In marine waters, chum fry, including summer chum fry, in shallow near-shore areas are likely to be preyed upon by mergansers and double-crested cormorants and possibly by western and horned grebes (Dave Nysewander, WDFW, pers. comm.). Common mergansers have been observed herding chum fry into shallow water and feeding in McAllister Creek (south Puget Sound) (Bill Tweit, WDFW, pers. comm.). As chum fry grow and move away from the near-shore area, they are likely to be preyed upon by double-crested and pelagic cormorants, mergansers, pigeon guillemots, gulls (especially Bonaparte's), terns, loons, grebes, and rhinoceros auklets. Marbled murrelets are not considered to pose any significant threat to chum fry, because they are currently at depressed population levels, and because they are plankton and larval fish specialists. When juvenile chum enter the open ocean, deep-water bird predators include common murres, shearwaters, Brandt's cormorants and puffins. Only bald eagles and osprey are likely to prey on adult summer chum.

Very little is known about the extent of bird predation on chum salmon. A study of marks made by predators on juvenile chum captured by beach seine, purse seine, and trawl at a range of depths in Masset Inlet, British Columbia has found marks attributed to birds in 6% of chum juveniles captured (Dawe, unpublished results). The proportion of chum in this study which did not escape bird predators is unknown. Dawe reports pigeon guillemots preying on schools of juvenile pink salmon but does not mention observing them preying on chum.

The majority of information on long-term sea bird population trends within Washington State has been collected on the outer Washington Coast and at Protection Island (near Discovery Bay). Little information exists for the Hood Canal or Sequim Bay areas. On the outer Washington coast, common murres underwent a population crash from about 30,000 birds to 2,400 birds in 1983-84, as a result of the 1983 El Niño (Wilson 1991). The population has increased since then to perhaps 7,000 birds (Ulrich Wilson, USFWS, pers. comm.). The trend in the murre population on Tatoosh Island differs from that of the rest of the coast in that it peaked at about 3,100 birds in 1991 but has declined since then. Double-crested cormorants on the outer coast have had a sharp decrease in breeding success, if not in numbers of adult birds, from between 400 and 500 nests in 1982 to essentially none in 1983-84. They experienced another decline associated with a milder El Niño in 1987-1988 (Wilson 1991), but since have rapidly recovered in number both on the outer coast and in Puget Sound (Ulrich Wilson, USFWS, pers. comm.). Brandt's cormorants nesting success during the 1980s has been similar to that of double-crested cormorants, however, during the 1987-1988 El Niño, Brandt's cormorants crashed and recovered a year earlier than double-crested cormorants, presumably because they nest later than double-crested cormorants (Wilson 1991). The effects of the 1987-1988 El Niño may have occurred too late to affect nesting by double-crested cormorants in 1987 but in time to affect Brandt's. Similarly, the waning of El Niño effects in 1988 may have occurred too late for double-crested cormorants but in time to permit Brandt's to nest successfully. Pigeon guillemot numbers on Protection Island increased from 1976 to 1989 and have decreased since then. There has been a large reduction, perhaps as much as 95%, in the numbers of horned and red-necked grebes in the Strait of Juan de Fuca over the last ten years. Gulls on Protection Island have shown a small but probably non-significant increase in recent years (Ulrich Wilson, USFWS, pers. comm.). During the 1960s, the rhinoceros auklet population on Protection Island was low (5,000-6,000 breeding pairs) until sheep were removed from the island. The population has since increased, peaking at 17,000 breeding pairs in 1976, but has declined to about 12,000 pairs today (Ulrich Wilson, USFWS, pers. comm.).

Hodges et al. (1996) has compiled Alaska water bird population trend data based on aerial surveys from 1957 through 1994. Potential chum predators monitored include mergansers and loons. Pacific, arctic, common, and red-throated loons have all declined in number since 1977, while merganser numbers have increased since 1977. It is not known if the Alaska data are applicable to Washington.

Most sea bird populations in the Strait of Juan de Fuca and Washington Coast have experienced declines or declines and recoveries during the time that summer chum have been declining. Given the relatively low numbers of summer chum relative to numbers of fall chum, it is unlikely that sea birds were a significant cause of summer chum decline.

2.2.3.6 Marine Mammals

Since the passage of the Federal Marine Mammal Protection Act in 1972, the populations of seals and sealions in Washington and other coastal states have steadily increased. Observations of predation by California sea lions (*Zalophus californianus*) and Pacific harbor seals (*Phoca vitulina*) on various salmonids have also increased, raising concerns about the impacts on depressed and other salmonid populations (NMFS 1997b).

Hood Canal - Pacific harbor seals are the primary pinniped species in Hood Canal, with an estimated current year-round population of over 1,500 individuals (Jeffries et al. 1999). Annually, peak abundance occurs in October, and the greatest concentrations are in the vicinity of the mouths of the larger river systems. Index counts of harbor seals have been conducted in Hood Canal by WDFW since 1983, and between 1983 and 1996 seal populations have increased approximately 5% annually (Steve Jeffries, WDFW, pers. comm.). Other pinneped populations in the region include an estimated 10-50 California sea lions and less than 10 Steller sea lions which also occur in Hood Canal (NMFS 1997).

Because of their small size, out-migrating chum salmon fry are not thought to be vulnerable to harbor seal or sea lion predation (NMFS 1997). Substantial chum fry predation by seals under unusual circumstances has been observed at the Puntledge River in British Columbia. Lighting on bridges near the river mouth illuminates outmigrating chum fry, and in one study harbor seal predation between April and June of 1995 has been estimated to be 3.1 million fry, or 7-31% of the year's production (NMFS 1997). Since similar conditions are not present in Hood Canal, harbors seals are unlikely to be significant predators on the region's chum salmon fry.

The predation by seals and sea lions on adult salmon has been well documented. NMFS (1997) reviews a variety of pinniped food habits studies for both harbor seals and sea lions, which show differing salmonid consumption rates depending on salmon abundance and the availability of alternate prey species. As an example, one 1980-82 study has shown that the percentage of seal scat samples containing salmonid remains was 10% in Grays Harbor and 28% in Willapa Bay (Reimer and Brown 1996). Estimates of salmonid consumption by pinnipeds in Oregon by Kaczynski and Palmisano (1992) have used rates of 10.8% of total biomass consumed for harbor seals and 10% for California sea lions.

NMFS (1997) presents an estimate of the annual prey biomass consumption (956 metric tons) by 1,036 harbor seals in Hood Canal. Using these consumption rates, the current harbor seal population of 1,500 animals in Hood Canal would consume 1,385 metric tons of prey biomass per year. If salmon constitute 10.8% of the diet (Kaczynski and Palmisano 1992), Hood Canal harbor seals could be taking a substantial number of salmon each year. Since summer chum salmon currently make up only about 1% of the total return of salmon (all species) to Hood Canal, seal predation rates on summer chum might be considered to be modest, unless seals are specifically targeting summer chum populations.

In the summer of 1998, WDFW began a multi-year study of harbor seal predation on adult salmon near the mouths of a number of Hood Canal summer chum salmon spawning streams; Big and Little Quilcene, Dosewallips, Duckabush, and Hamma Hamma rivers (Jeffries et al. 1999). Direct observations of seal/salmon interactions have been made in the vicinity of the river mouths on a three day per week schedule, beginning in the first week of September, and ending just before the Thanksgiving holiday. Preliminary results from this study indicate that harbor seals have taken substantial numbers of adult salmon during the summer chum migration period. Estimated daylight total salmon predation numbers for each observation area are: 243 fish in Quilcene Bay, 113 fish at Dosewallips River, 96 fish at Duckabush River, and 277 fish at Hamma Hamma River. These predation observations could potentially include summer chum salmon, fall chum salmon, coho salmon, and chinook salmon (pink salmon were not present in 1998). For two systems, Quilcene Bay and the mouth of the Dosewallips River, estimates have been made of the percent chum salmon taken by seals during predation events when prey species could be identified; 73% chum salmon at Quilcene Bay (11 of 15 kills), and 62.5% at Dosewallips River. While the high chum salmon predation rates include both summer and fall chum (there are insufficient observations to reliably estimate just summer chum predation), there clearly has been substantial seal predation on the 1998 return of adult summer chum salmon in Hood Canal.

The lack of census data for harbor seals and sea lions in Hood Canal during the 1970s makes a direct examination of the possible relationship of pinniped predation to the decline of summer chum salmon impossible. The evidence for the substantial increase in the Hood Canal seal population since 1983, indicates that in the late 1970s, seals were in much lower abundance in Hood Canal. Sea lions have a relatively minor presence in Hood Canal.

In conclusion, it seems unlikely that pinniped predation has been a significant contributor to the original decline of Hood Canal summer chum salmon. It is apparent, however, that because of the now locally abundant seal populations and the 1998 study preliminary results, showing substantial salmon predation at the mouths of summer chum streams, harbor seals may be an important factor that could slow the recovery rate of Hood Canal summer chum salmon.

Strait of Juan de Fuca - The NMFS (1997b) report does not provide estimates of pinniped population sizes for the eastern Strait of Juan de Fuca. They do identify Harbor seals and Steller sea lions as being present in marine areas adjacent to summer chum streams in the region. There have been no reports of unusual levels of pinniped interactions with summer chum salmon, and it is unknown if seals or sea lions have contributed to the observed summer chum salmon decline. However, pinniped predation may slow the recovery of summer chum salmon in this region.

2.2.3.7 Conclusions

Competition and predation impacts on summer chum salmon - Fresh (1997) offers insight into the difficulties in measuring the impacts of competition and predation, and observes that "... available data will rarely if ever be unequivocal." The above review supports that assessment. There is little direct evidence available to either document or refute the possibility of substantial competition or predation effects on summer chum salmon. Of the various potentially competitive or predatory species discussed above, only the increased abundance of hatchery origin fall chum salmon comes close to matching the period of decline in the summer chum salmon populations. However, even this potentially negative relationship is contradicted by a lack of direct synchrony, ecological differences between summer and fall juvenile chum in marine waters, and the recent increases in summer chum salmon. While the currently available information suggests that the hatchery fall chum salmon program is not having a major impact on summer chum salmon survivals, uncertainty still exists and may warrant further investigation. The generally high numbers of other hatchery salmonids released into Hood Canal streams during the period of decline are likely to have contributed to the decline of summer chum stocks in that region.

A second important conclusion relating to potential competition and predation effects on Hood Canal and Strait of Juan de Fuca summer chum salmon, is that increases in abundance of two species ***after the decline*** may currently be affecting the survivals of summer chum salmon, and may ultimately slow recovery. Wild fall chum salmon have recently been very successful in Hood Canal, with some annual escapements exceeding 100,000 spawners. There is a possibility that redd superimposition by fall chum salmon could reduce intergravel survivals of the earlier spawned eggs and alevins of summer chum salmon. A second species with the potential to affect the recovery of summer chum salmon is the Pacific harbor seal. Over the last 25 years, harbor seal populations in Hood Canal and the Strait of Juan de Fuca have increased at about 5% per year and are now very abundant. Additionally, preliminary results from a 1998 WDFW seal predation study in Hood Canal shows that there are substantial levels of seal predation occurring on depressed summer chum salmon populations.

2.2.4 Habitat

Of the four general topics included in this discussion of factors for decline, habitat issues have a different relationship to changes in survival and production of summer chum salmon. The basic approach of Part Two is to document and evaluate any changes in factors affecting summer chum production that have occurred in concert with the specific recent periods of decline in Hood Canal and the Strait of Juan de Fuca regions. In general, habitat loss is a long-term, cumulative process that leads to gradual reductions in the productivity of fish and wildlife species. It is rare for abrupt habitat change to occur on a regional scale and affect salmon in multiple streams across a number of watersheds. Examples of large scale natural habitat disruptions would be the recent volcanic eruption of Mount St. Helens, and the forest fire that burned at least half of the Olympic Peninsula in the year 1308 (USFS and WDNR 1994). Nearly all human-caused habitat loss occurs at a much smaller scale; at the watershed, stream, or stream reach level. Some types of habitat impact can cause substantial local losses to the productive capacity of the freshwater environment, e.g. dam construction, or forest road building and logging. Other impacts like land clearing, stream bank armoring, and increases in impervious surfaces have smaller immediate incremental effects, but added together and over time they can have a major negative impact. For a discussion of local habitat impacts on individual streams see Part Three, section 3.4 Habitat.

There are no observed region-wide changes in habitat that correspond in timing to the 1979 decline of summer chum salmon in Hood Canal, or to the 1989 decline in the Strait of Juan de Fuca. Cumulative habitat impacts have contributed to the decline, however, and habitat restoration must be a major part of the recovery of summer chum salmon in the two regions. Short- and long-term changes in habitat on a local scale have reduced the range of summer chum salmon, have affected their survival and productivity in streams and estuaries, and have caused or contributed to the extirpation of populations of summer chum salmon from streams in the region. These habitat related impacts have reduced the resiliency of summer chum salmon, and in combination with the other factors for decline, have led to the current depressed status of these stocks of fish. The primary objective of this recovery plan, to have healthy and harvestable stocks of summer chum salmon, cannot succeed without a strong and comprehensive habitat protection and restoration effort.

The following discussion will provide a review of the general habitat needs and factors limiting production for summer chum salmon. Two case studies from Hood Canal streams are also presented to show how habitat alterations can cause severe impacts on the survival and production of summer chum salmon. This section ends with a discussion of the contribution of habitat change to the decline of summer chum salmon in the region.

2.2.4.1 General Summer Chum Habitat Overview

Suitable salmonid habitat, including that of summer chum salmon, needs to provide for six key life requirements for them to be productive and successful. Salmonids need adequate quantity and quality of water. They need food for survival and growth. They need forms of shelter that provide protection from predators and allow them to minimize energy loss. Salmonids need to be able to move within and between habitat types to fulfill their life requirements. They need clean and relatively stable gravel areas to reproduce. These life requirements are affected by both natural processes and human influences on those natural processes.

Many reviewers have summarized the life histories and habitat requirements of salmon, and the effects of natural and human events and activities on salmonid survival and production. Palmisano et al. (1993), NRC (1996), and Spence et al. (1996) all provide good reviews of these issues and all have been utilized in the preparation of this plan.

Summer chum salmon habitat includes all of the places where they spawn, feed, grow, and migrate. In the broadest sense, maintaining and protecting this habitat also protects the habitat of the prey species that make up the salmonid diet, and those upland areas that directly affect the waters where salmonids actually live. Summer chum salmon are generally found in the lowermost reaches of streams, however, their habitat is affected by overall watershed habitat conditions. Some streams like the Skokomish River have fairly big watersheds, while others like Big Beef Creek and Snow and Salmon creeks are only medium sized watersheds. Estuaries, near and off shore marine areas of Hood Canal, the Strait of Juan de Fuca and the open ocean are all part of summer chum salmon habitat.

Streams in the HC-SJF region course through wilderness areas and national parks, industrial and non-industrial forests, agricultural land, and rural and suburban residential landscapes. Land uses adjacent to nearshore marine areas range from state and county parks, federal refuges to rural and urban residential development to industrial harbors. All of these land uses affect the survival and productivity of summer chum salmon and must be considered in the recovery effort.

The life requirements for chum salmon are influenced through a combination of interrelated physical, chemical and biological processes, and habitat conditions occurring over both short- and long-time scales, and across a variety of land forms. Many of these relationships are not well understood. Quite often it is very difficult, if not impossible, to draw quantitative relationships between habitat conditions and salmonid survival and production. Further, freshwater habitat/production relationships can be confounded by ocean survival conditions, inter- and intraspecific competition and predation relationships, and by a variety of fishery impacts. Nonetheless, chum salmon life requirements appear to be affected by habitat conditions in the following manner:

C Water quantity (flow regime) is affected primarily through basin hydrology, which is manifested as instream flows. Instream flows are affected by: 1) natural climatic, topographic geologic, soils, and vegetative conditions; 2) land use activities; and 3) other in-and out-of-stream uses of water (hydropower, irrigation).

C Water quality is affected in part by basin hydrology and instream flows. It is also influenced by: 1) upslope events such as soil erosion and land slides; 2) by the condition and extent of riparian (near water) vegetation; 3) by the extent and function of wetlands; 4) by a variety of natural and chemical contaminants; 5) by stream channel and marine habitat stability and complexity; and 6) by in-water activities such as dredging.

C Food supply and availability is affected by: 1) instream flows; 2) sediment quality, delivery and routing; 3) water quality; 4) riparian, wetland, and marine vegetation; 5) stream, lake and marine habitat complexity; 6) the numbers of returning adult anadromous or resident spawning salmonids; and 7) by predator-prey and species competition relationships.

- Shelter for rest and cover is influenced by hydrology, water quality, sediment quality, delivery and transport, and by the extent and condition of riparian vegetation. Stream channels which possess varied and complex habitat features such as large woody debris, rocks and boulders, and channel features such as overhanging banks, and a variety of water depths and velocities, provide abundant resting and hiding shelter.

- Fish access and passage are affected by hydrology, water quality, sediment quality, delivery and routing, riparian and wetland condition and extent, and floodplain connectivity. Fish passage is further influenced by natural obstacles such as waterfalls and human structures such as dams, dikes, and culverts, and by some docks, breakwaters and piers in marine areas.

- Reproduction is influenced by all the above, but primarily by instream flows, sediment transport, and water quality.

To sustain and recover summer chum salmon populations, functional and accessible fish habitat is essential. This includes both existing salmonid habitat in its present condition, as well as degraded habitat in need of restoration. It will also require protection and restoration of the productive capacity of habitat. Areas used by summer chum salmon to complete their life history needs must be protected or restored, including instream, riparian, estuarine, and wetland ecosystems, and the upland activities and processes that affect them.

Protection of the existing habitat base should be the first priority for habitat actions. Such protection is usually the most cost-effective initial mechanism available to ensure summer chum sustainability. It is immediate, efficient, and can slow or stop the trend of habitat loss. It also retains current summer chum production capacity, and provides a foundation for future recovery and growth. Protection is also relatively inexpensive when compared to the cost of restoring summer chum salmon habitat.

However, given the current degraded state of summer chum habitat in the region, restoration must also be initiated. Restoration is a long-term activity. In this region there are many actions that could be initiated in the short term, however others may take many years to accomplish because of the cost and because often a period of natural watershed healing is needed. Habitat restoration is a relatively new and experimental science, and is more costly than protection. Restoration will be critical in those areas where the existing habitat base is insufficient to sustain summer chums, or where habitat degradation or loss is a key cause of stock decline.

Protection and maintenance of wild salmonid habitat requires recognition of the continuum of aquatic and terrestrial physical and chemical processes, biological systems, and human influences on that continuum (Vannote et al. 1980). The stream continuum exists in a longitudinal fashion from the smallest rivulet, down through increasingly larger streams and rivers, into estuaries and eventually to the open ocean. Downstream processes are linked to upstream processes through routing of water, sediment, and organic matter. Chum salmon in particular, since they spawn and rear very near stream mouths, are especially susceptible to the entirety of habitat conditions and processes that occur within a watershed, and those that affect estuarine, marine and open ocean habitats within their migratory range.

2.2.4.2 Historical Habitat Impacts On Summer Chum Salmon

The following discussion reviews two examples of Hood Canal streams that have been affected by substantial habitat alterations; resulting in serious reductions in summer chum salmon survivals in one stream, and contributing to the extirpation of summer chum salmon in the other stream. These examples are presented here only to provide an overview of how changes in habitat quality and quantity can impact summer chum salmon, and are not meant to be an examination of all habitat problems in these streams. A comprehensive assessment of habitat-related factors affecting summer chum salmon in these two streams, and in all other summer chum streams in the region is provided in Part Three, section 3.4 Habitat and in detailed watershed descriptions in Appendix Report 3.6.

Big Quilcene River Summer Chum Salmon - The Big Quilcene River flows in a south easterly direction from its headwaters in the Olympic Mountains for 18.9 miles to its confluence with Dabob Bay and Hood Canal. The basin has a drainage area of about 70 square miles (Williams et al. 1975). With the exception of a small section of the extreme upper watershed, the entire drainage above river mile 4.0 is in the Olympic National Forest (USFS and WDNR 1994), and is managed for forestry and recreational uses. Below river mile 4.0, land uses are predominately residential, and some shellfish culture and limited agriculture.

Big Quilcene River habitat impacts - The habitat conditions of the watershed are described in detail in the Big Quilcene Watershed Analysis (USFS 1994), and the following are selected quotations regarding habitat impacts from the Executive Summary of that report.

> "Pre-management disturbance regimes dictating vegetation patterns, sediment flow, and hydrologic response were influenced by wildfires. These fires covered thousands of acres at a time with frequencies of every 100-200 years. Large pulses of sediment routed through the watershed after fires from landslides on steep slopes. These sediment pulses most likely caused dramatic changes in channel location of the lower mainstem as the Big Quilcene River deposited this sediment. High intensity storms, such as rain-on-snow may have produced smaller sediment peaks as the watershed was recovering from these fires, particularly from landforms noted as being less resilient to changes in hydrology. Road construction and timber harvest since the 1930s has produced sediment disturbances similar to those after wildfires but without recovery intervals between disturbances. Urban development and in-stream removal of large wood along the lower mainstem have reduced channel habitat diversity by straightening the channel and removing roughness in the channel. Water diverted from the upper watershed and sediment deposition in the lower mainstem may have reduced pool volume and channel depth. Vegetation removal has altered temporal and spacial distribution of vegetation changing the character of habitat structure and distribution.
>
> Present day demands for high quality and quantity of water for a variety of uses is a major issue in the watershed, particularly during low flow periods. The Big Quilcene River supplies water for municipal and commercial uses and as well for aquatic species including salmon.
>
> This assessment shows a generally poor condition of physical stream habitats, and thus, productive capacity, within locally significant reaches of stream. Habitats within the WAU are poorly distributed and quite dynamic under natural conditions. It is not possible to correlate fish populations (either

> standing crop or smolt output) with habitat conditions due to the effect of hatchery production. Instream flows during the low-flow periods likely create a bottleneck in fish production, particularly for highly valued anadromous fishes in the lowest reaches of streams in the WAU. Water management and conversion of existing uses of the forest lands to urban areas or interfaces may be more critical to the conservation and management of fish habitat and populations than patterns of forest disturbance."

The above quotation details only the effects of sedimentation on the river channel. Part Three, section 3.4 Habitat and the Big Quilcene River watershed description in Appendix Report 3.6 provide more detailed descriptions of sedimentation and other habitat problems in the basin.

The above described habitat conditions cause major problems for summer chum salmon in the lower Big Quilcene River. Sediments from the upper watershed are transported downstream by high flows, and aggregate in the low gradient reaches of the lower river. As the channel fills with sediments, local flooding impacts are exacerbated, resulting in landowner desires to channelize the river, armor stream banks, and install levees. Unfortunately, these are the same stream reaches used by summer chum salmon for spawning and the subsequent incubation of eggs and alevins. Most of the remedial measures used to control flood impacts result in reduced habitat quality, affecting the survival of the local summer chum salmon population.

Habitat impacts on summer chum salmon - A recent example demonstrates the type of impact that even a single flood control project can have on the salmon using the stream. In December of 1993, an intense rain storm resulted in flooding on the Big Quilcene River, and caused a breech in a levee on the lower river. The affected landowner, fearing damage to adjacent structures, conducted an unauthorized channelization project, removing stream bottom materials from approximately a third of a mile of the channel. This project took place at a time period when the eggs and alevins of summer chum salmon were incubating in the stream gravels. An on-site inspection by WDF staff found that the entire stream bottom in the affected reach had been severely disrupted, resulting in the total loss of all incubating eggs and alevins. A subsequent evaluation determined that 29% of the total production of the 1994 summer chum salmon spawning in the river had been destroyed by this project (Uehara 1994). This unfortunate impact on the survival of summer chum salmon in the Big Quilcene River occurred in a year when only 89 total spawners had returned to the river (Uehara 1994), and when the stock was considered to be in critical status (WDF et al. 1993).

Skokomish River Summer Chum Salmon - The Skokomish River is the largest stream system in Hood Canal, and historically has produced a major portion of Hood Canal salmon runs (Smoker 1952). Two large tributaries, the North and South forks, come together at river mile 9.0 to form the mainstem Skokomish River. Because of the extensive amount of habitat potentially provided by the Skokomish system, it is likely that with pristine conditions (pre-development) this watershed was the largest producer of summer chum salmon in Hood Canal. Most of the system has under gone extensive habitat alterations, however, with negative consequences for indigenous stocks of salmon. The following example will discuss only the impacts of a single limiting factor (water withdrawal) on the summer chum salmon of the North Fork Skokomish River. For a more detailed discussion of the habitat limiting factors in the entire Skokomish River basin, see Part Three, section 3.4 Habitat and the Skokomish River watershed description in Appendix Report 3.6.

North Fork Skokomish River habitat impacts - The North Fork Skokomish River flows for 41.9 miles out of the Olympic Mountains in a generally southerly direction to its confluence with the South Fork (Williams et al. 1975). Over 100 tributary streams join the mainstem of the North fork to form a watershed of 118 square miles (FERC 1996). Two major features in the system are lakes Cushman and Kokanee which are formed by hydroelectric dams, and represent the upper limit of anadromous fish utilization. The area above Lake Cushman is almost entirely within the Olympic National Park, which maintains the watershed and adjacent lands in a protected, natural condition. Below the reservoirs, land use is predominately forestry, with some residential and agriculture uses near the confluence with the South Fork (FERC 1996).

The two hydroelectric dams were built on the North Fork by the city of Tacoma; Dam No. 1 at river mile 19.6 was completed in 1926, and Dam No. 2 at river mile 17.3 was finished in 1930. The upper dam inundated the pre-existing Lake Cushman and increased its size from about 322 surface acres to its present 4,010 acres. Mean annual stream flow at the lower dam site has been estimated to be approximately 748 cfs. After the construction of the North Fork dams, virtually all flow was diverted from the system at the lower dam until 1988, when 30 cfs was provided below the project (FERC 1996). This lack of water discharge from the dams combined with a partial diversion of the largest downstream tributary (McTaggert Creek), reduced the flows in the North Fork to the point that at certain times of the year all of the water disappeared into the ground, and portions of the stream were dry (WDF 1957). The 1957 WDF report also documented a specific observation of a section of the North Fork with no surface flow in August 1954, going dry first at a point about a half mile above the mouth. These conditions of extreme low flow likely occurred most often in late summer, at the time when summer chum salmon needed to access the stream for spawning.

South Fork and mainstem Skokomish River habitat impacts - The South Fork Skokomish River flows for 27.5 miles in a southeasterly direction to its confluence with the North Fork. From the joining of these two major tributaries, the mainstem flows in a generally easterly direction for nine miles to its mouth on the southern end of Hood Canal (Williams et al. 1975). Most of the 124 square miles of drainage area are in the Olympic National Forest, with private forest lands, agriculture, and residential uses in the lower watershed and along the mainstem (FERC 1996).

The same habitat alteration processes described above for the Big Quilcene River (USFS and WDNR 1994) have also occurred in the South Fork and mainstem Skokomish, only on a much larger scale. Stream flows exhibit tremendous volatility; with extreme flows during the period of record (1931-1996; South Fork Skokomish USGS gage 12060500) varying from a high discharge of 21,600 cfs to a low of just 62 cfs (Wiggins et al. 1997).

Massive downstream sediment transport occurs from the South Fork, filling the mainstem Skokomish River channel. These sediments are being released from heavily logged areas of the upper watershed (FERC 1996). Over the years, an extensive system of levees has been constructed along the lower river to protect low-lying, flood prone lands. As the river channel between the levees has filled with sediments from upstream, river bed elevations have risen, and flooding of lands adjacent to the lower river have increased in frequency (FERC 1996). Multiple, damaging floods now occur virtually every year in the Skokomish River lowlands.

Habitat impacts on summer chum salmon - Summer chum salmon probably ceased to exist as a self-sustaining stock in the Skokomish River system in the late-1960s or early 1970s. Only limited information on the population size prior to that time period exists. Between 1935 and 1953 annual tribal net catches of summer chum salmon in the river in September ranged from 61 to 986 fish (Smoker et al. 1952). An estimated 3,000 to 4,000 summer chum spawners were observed in the South Fork and mainstem on October 1, 1954 (WDF 1957). A WDF assessment of Puget Sound salmon escapements for the years 1966-1971 estimated the Skokomish summer chum salmon average escapement to be approximately 300 spawners, and characterized the population as having "a negligible level of abundance" (Williams et al. 1975). In 1974 a WDF salmon status review listed Skokomish summer chum salmon adult returns as "few," with escapement levels "unknown" (WDF 1974). By the following year, summer chum salmon were no longer included as a viable stock in the Skokomish system in annual WDF status assessments (WDF 1975). A state-wide inventory of salmon and steelhead stocks in 1992 (WDFW and WWTIT 1994), did not find evidence of a viable, self-sustaining summer chum stock in the system. The question of the status of the small numbers of summer-timed chum salmon that are sporadically observed in the Skokomish has been reexamined for this recovery planning effort, and the same conclusion has been reached; there is currently no evidence of a viable summer chum stock in the system (see discussion in Part One).

North Fork summer chum salmon were likely extirpated from that stream as early as 1956. A Skokomish tribal elder, Joe Andrews Sr., documented this loss of summer chum salmon in the North Fork Skokomish River in a 1991 interview conducted by the British Columbia Indian Language Project. Speaking of the North Fork Skokomish River:

> "Frank Allen, however, especially liked to smoke a summer run of dog salmon, a yellowish-colored salmon that came upriver between July and September. Apparently this run was no longer available after around 1956." (Bouchard and Kennedy 1997).

Supporting this account is a 1957 WDF report which stated:

> "The chum salmon population now using the North Fork would not be especially affected by this extreme low flow and dry stretch. The chum salmon enter in mid-November after the river has recovered and the dry period is over." (WDF 1957).

This reference indicates that only fall-timed chum salmon were using the North Fork in 1957. The lack of adequate migration and spawning flows in the North Fork after the construction of the dams presumably has been a major contributor to the loss of summer chum salmon in that stream.

The impacts of habitat alteration have been devastating for those species or stocks of salmon that spawn in the South Fork and mainstem Skokomish in late summer or early fall months. In 1961, WDF staff began to conduct regular spawning ground surveys on the South Fork and mainstem Skokomish during September and October. Since that time, summer chum have been only rarely observed; and over the last 20 years the numbers observed are considered to be too low to represent a self-sustaining stock. The extreme low flows during the early spawning periods, followed by severe flooding and massive sediment movement have created a situation where eggs deposited by early spawning chum salmon using riffles in the main river channels have little chance of survival. These conditions have likely played a major role in the extirpation of the summer chum salmon of the Skokomish system.

2.2.4.3 Conclusions

Although no single region-wide habitat alteration is apparent during the periods of summer chum salmon decline in Hood Canal or the Strait of Juan de Fuca streams, the cumulative impacts of habitat loss has been a significant factor in the lowered survival and production of these fish. As shown in the case studies above, disturbance of critical habitat elements can cause reductions in survivals, and in the worst case, extirpation of stocks. Local summer chum salmon may be more vulnerable to these kinds of impacts than other salmonids, because they are at the southern extent of their distribution and probably lead a more tenuous existence than more northern stocks.

While the examples presented for the Skokomish and Big Quilcene rivers are extreme cases, similar but smaller scale habitat loss has occurred on all summer chum salmon streams in the region. These habitat impacts lower the resiliency of the summer chum populations, exacerbating any additional negative impacts on the survivals of these fish. Habitat change has been a major contributor to the decline of summer chum salmon in Hood Canal and the Strait of Juan de Fuca (see section 3.4 and Appendix Report 3.6).

2.2.5 Harvest

The early history of fisheries in Hood Canal and Strait of Juan de Fuca is summarized above in the Harvest Data discussion of Part One (section 1.4.3). The "modern" era of regional salmon management began with the 1974 Boldt Decision on Indian fishing rights. Traditional Puget Sound fisheries changed in 1974 from a mixed-stock harvest approach to a more terminal pattern of fishing, to accommodate the necessary allocation of returning fish to tribal and non-tribal fisheries, and to provide for better fishery management. This resulted in the movement of new and intensive non-Indian and tribal net fisheries into the Hood Canal terminal area, which was previously a salmon preserve that was closed for net fisheries and open for sport fishing. The two summer chum stocks in Discovery and Sequim bays have been almost completely protected from harvest within the bays (terminal areas). The summer chum stocks of both regions, however, are affected by harvest in pre-terminal areas, including catches in the Strait of Juan de Fuca by both U.S. and Canadian fishers.

Of the various activities that can affect the success of a salmon population, harvest is usually the only factor for which the numbers of fish taken from the population are routinely quantified. The effort to account for the numbers of fish taken in various fisheries has a number of problems, one of which is the allocation of mixed stock catches to their appropriate stock of origin. In an attempt to deal with this problem for the purposes of this recovery planning process, an improved runsize data base has been developed (see Part One, 1.4.4 Run Size). These summer chum salmon runsize data will be used in section 3.5, Harvest Management, to estimate exploitation rates to evaluate the contribution of fishery impacts to the decline of summer chum salmon. These harvest data are thought to provide a reasonable measure of the general impacts of fishing activities on summer chum salmon.

2.2.5.1 Pre-terminal Harvest

> **Pre-terminal Area**
>
> ***Marine waters where specific stocks (or groups of stocks) are mixed with fish returning to other regions. These areas for summer chum salmon include all marine waters of Admiralty Inlet, the Strait of Juan de Fuca, and the Pacific Ocean seaward of Hood Canal and Discovery, Sequim, and Dungeness bays.***

The pre-terminal management areas for summer chum salmon include all marine waters seaward of Hood Canal and Discovery and Sequim bays. Summer chum salmon are harvested in these areas during fisheries for other species of salmon, primarily pink and sockeye salmon. During the time period that summer chum salmon are present, management authority is vested in the Pacific Salmon Commission (PSC) for most of the pre-terminal areas (Admiralty Inlet excepted). Since these PSC fisheries are directed at Fraser River pink and sockeye stocks, seasons and exploitation rates are based on the annual abundance of those species. Summer chum salmon have been incidentally harvested during these fisheries at exploitation rates based on the needs of Fraser River runs.

Accounting for all harvests of summer chum salmon has been a desired objective of the on-going restoration planning effort. Accordingly, beginning in 1995, tissue samples for genetic profiling of summer-timed chum have been collected from a major Strait of Juan de Fuca fishery (Canadian Area 20). The WDFW Genetic Lab analyzed the resulting samples using allozyme electrophoresis techniques, and estimated that for the 1995-1997 seasons Hood Canal and Strait of Juan de Fuca summer chum salmon contributed an average of 49% of the chum salmon sampled. Annual results were; 31% in 1995, 68% in 1996, and 49% in 1997 (Larry LeClair, WDFW, personal communication). The sample data were used to estimate total annual catch of Hood Canal and the Strait of Juan de Fuca summer chum salmon in PSC fisheries prior to September 16 for each year from 1974 through 1997 (see Appendix Report 1.3 for methods). Admiralty Inlet summer chum harvests were apportioned to Hood Canal and the Strait of Juan de Fuca using run-reconstruction methods.

An examination of 1974-1997 U.S. pre-terminal exploitation rate on an annual basis (Table 2.8) shows that there has been no meaningful change in the exploitation rates on summer chum salmon corresponding to the decline of Hood Canal summer chum stocks in 1979 and subsequent years, or for Strait of Juan de Fuca stocks beginning in 1989.

Table 2.8. Annual U.S. pre-terminal exploitation rates and harvest for Hood Canal and the Strait of Juan de Fuca summer chum salmon stocks, 1974 to 1998.

Return years	Pre-terminal exploitation rate	Estimated harvest	Return years	Pre-terminal exploitation rate	Estimated harvest
1974	0.023	378	1987	0.024	147
1975	0.019	600	1988	0.032	310
1976	0.045	3,383	1989	0.081	426
1977	0.042	785	1990	0.022	45
1978	0.025	719	1991	0.088	230
1979	0.098	1,025	1992	0.027	129
1980	0.031	557	1993	0.065	98
1981	0.095	666	1994	0.026	80
1982	0.036	428	1995	0.006	66
1983	0.059	279	1996	0.005	103
1984	0.014	73	1997	0.004	46
1985	0.101	487	1998	0.008	41
1986	0.018	167			

A substantial increase in Canadian Area 20 exploitation rates is apparent during the four year period from 1989 through 1992 (Table 2.9). The 1989 and 1990 Area 20 exploitation rates were respectively the highest (43.2%) and third highest (33.4%) in the 24 year data base. The two following years had exploitation rates of 18.5% (1991) and 20.6% (1992); both years well above the 25 year average rate of 11.1%. Since 1989, the Canadian Area 20 fishery harvested an average of 76% of the total pre-terminal catch. For the 1993-1998 period, Area 20 pre-terminal exploitation rates returned to lower levels, averaging 4.7% and ranging from 1.5 to 14.2% annually. The relatively high exploitation rates between 1989 and 1992 coincided with the severe drop in escapements of Strait of Juan de Fuca summer chum salmon beginning with the 1989 return year.

Table 2.9. Annual Canadian Area 20 exploitation rates and harvest for Hood Canal and the Strait of Juan de Fuca summer chum salmon stocks, 1974 to 1998.

Return years	Area 20 exploitation rate	Estimated harvest	Return years	Area 20 exploitation rate	Estimated harvest
1974	0.086	1,399	1987	0.063	390
1975	0.034	1.064	1988	0.075	738
1976	0.075	5,705	1989	0.432	2,273
1977	0.049	913	1990	0.334	696
1978	0.025	701	1991	0.185	438
1979	0.057	591	1992	0.206	980
1980	0.053	980	1993	0.044	67
1981	0.131	915	1994	0.142	451
1982	0.187	2,219	1995	0.042	458
1983	0.006	28	1996	0.015	338
1984	0.062	314	1997	0.019	198
1985	0.336	1,620	1998	0.018	98
1986	0.088	796			

2.2.5.2 Terminal and Extreme Terminal Harvest

As defined by the co-managers, the terminal fishery management areas for the region include most of the marine waters of Hood Canal (Management Areas 12, 12B, and 12C). Extreme terminal management areas include marine areas 12A, 12D, Discovery and Sequim bays (Management Area 6B), Dungeness Bay (6D), and all rivers where summer chum salmon are present. Hood Canal is intensively fished by tribal and non-tribal net fishers, while the Strait of Juan de Fuca terminal area bays are essentially regulated for no net fishing. Because of these patterns of regulation and fishing, the following discussion will focus on Hood Canal terminal area harvest.

Terminal Area

Marine waters near the ultimate freshwater destination of specific salmonid stocks (or groups of stocks) where they have separated from fish returning to other regions.

Extreme Terminal Area

Marine or freshwater areas where salmonids of a single stock or management unit have separated from fish of other stocks.

As tribal and non-tribal net fisheries moved into Hood Canal in the years following the 1974 Boldt Decision, fishery exploitation rates changed dramatically for most salmon stocks in the region. Four salmon species were present as both wild and hatchery populations in Hood Canal (sockeye excepted), and fishery managers were faced with the problem of run timing overlaps throughout the fishing season. In an attempt to deal with this problem, the wild and hatchery components of each species were designated as having either "primary" or "secondary" management status (HCSMP 1986). Primary stocks would be managed for directed fisheries in mixed stock fishing areas. Secondary stocks would be subjected to seasons and exploitation rates in mixed stock areas that were suitable for primary stocks present in the same areas. The co-managers designated Hood Canal summer salmon to have a "secondary stock" management status, which meant that any harvest would be incidental to fisheries directed at other species; mainly coho and chinook salmon which had a primary management status. Mixed stock exploitation rates and seasons were established annually based on the abundance of coho and chinook salmon, resulting in high exploitation rates on summer chum salmon in some management areas. Tynan (1992) examined the effect of terminal harvest on summer chum escapements for the years 1968-1991, and concluded that high exploitation rates had contributed substantially to reduced escapements.

The issue of harvest impacts has been reexamined as a part of this restoration planning effort (see <u>Part Three</u>, section 3.5 <u>Harvest Management</u>). The newly derived runsize and exploitation rate estimates are described in <u>Appendix Report 1.3</u>, and are used in the following discussion.

Pre-terminal exploitation rates did not show a meaningful change in the years before and after 1979, but Hood Canal terminal exploitation rates went from essentially zero to rates that ranged between 14.7% to 71.9% for the years 1975-1991. Total exploitation rates (including pre-terminal harvest) ranged from 21.4% to 80.6% for the same span of years (Table 2.10). During the first six years of the Hood Canal fisheries (1974-1979), summer chum salmon total exploitation rates averaged 30.8%, and ranged from a low in 1974 of 11.1% to a high of 59.7% in 1976. The return in 1976 was in excess of 74,000 fish, and even with the high exploitation rate, over 27,000 spawners escaped to Hood Canal streams. From 1980 through 1991 Hood Canal summer chum salmon were subjected to high total exploitation rates (averaging 57.1%), with the majority of the impact occurring in the terminal area fisheries (average 46.9% exploitation rate).

Hood Canal summer chum escapements began to decline precipitously in 1979. Total exploitation rates in 1979 were a relatively modest 30.2%, and the period of consistently high exploitation rates began the following year (Table 2.10). The 1979 escapement was likely depressed by environmental conditions that resulted in record low returns of chum salmon statewide in that year (see discussion in section 2.2.2 Climate). After 1979, summer chum escapements and runsizes dropped in concordance with the increased total exploitation rates imposed on the returns (Table 2.11). In 1992 co-managers began to adopt protective harvest management provisions, which included time and area closures and mandatory release of summer chum salmon in most fisheries. The result was the elimination of nearly all terminal area harvest, with exploitation rates ranging from 0.3% to 2.1% for the 1993-1998 seasons (Table 2.10). With virtually all of the terminal run escaping, the number of summer chum spawners in Hood Canal streams averaged over 9,000 fish per year over the last five years (Table 2.11).

Table 2.10. Annual terminal and total exploitation rates for Hood Canal summer chum salmon stocks, 1974 to 1998. [1]

Return years	Terminal exploitation rate	Total exploitation rate	Return years	Terminal exploitation rate	Total exploitation rate
1974	0.002	0.111	1987	0.719	0.806
1975	0.254	0.308	1988	0.367	0.474
1976	0.476	0.597	1989	0.352	0.864
1977	0.224	0.316	1990	0.347	0.702
1978	0.164	0.214	1991	0.388	0.660
1979	0.147	0.302	1992	0.064	0.296
1980	0.624	0.708	1993	0.021	0.130
1981	0.348	0.574	1994	0.011	0.179
1982	0.448	0.671	1995	0.003	0.052
1983	0.685	0.750	1996	0.006	0.026
1984	0.490	0.567	1997	0.019	0.043
1985	0.300	0.737	1998	0.007	0.003
1986	0.565	0.671			

[1] Summer chum salmon returning to the Hood Canal terminal area experience varying exploitation rates in the various management units. See Part Three - section 3.5 Harvest Management for discussion.

Table 2.11. Five year average summer chum salmon pre-terminal, terminal, and total exploitation rates and escapements for Hood Canal stocks, 1974 to 1998.

Return years	Pre-terminal rates (%)	Terminal rates (%)	Total exploitation rates (%)	Hood Canal escapements
1974-78	8.5	22.4	34.3	17,773
1979-83	15.1	45.0	61.1	3,238
1984-88	16.3	48.8	65.8	1,760
1989-93	29.6	23.4	53.6	978
1994-98	5.7	0.9	6.7	9,028

2.2.5.3 Conclusions

Exploitation rate estimates for Hood Canal and the Strait of Juan de Fuca summer chum stocks show increases in exploitation rates that relate to the declines in both regions. In the case of Hood Canal summer chum salmon, the added impacts of indirect harvests in the terminal area fisheries (after 1974) combined with a relatively consistent level of pre-terminal catch have contributed substantially to the decline and subsequent continuing low production levels. The fact that these stocks are at the southern limit of summer spawning chum salmon may mean that they have a naturally lower level of productivity, making them less able than wild fall chum stocks to be successful with levels of exploitation rates shown in Table 2.11 (34% to 66%).

Strait of Juan de Fuca summer chum salmon declined abruptly in 1989, which was the same year that the Canadian pre-terminal exploitation rate peaked at 43.2% (Table 2.9), a fourfold increase from the 1974 to 1998 mean of 11.1%. Canadian pre-terminal exploitation rates in the following three years ranged from 18.5% to 33.4%, and were substantially higher than average. These higher exploitation rates likely contributed to the lowered escapements of summer chum salmon in the streams of Discovery and Sequim bays after 1988.

2.3 Rating of Factors For Decline

2.3.1 Introduction

The above discussions of factors for decline have considered the impacts of individual factors as if no other impacts were occurring. It is clear, however, that the declines of summer chum salmon in Hood Canal and the Strait of Juan de Fuca have been the result of the cumulative impacts of a number of factors. This section will rate the various factors for decline and discuss the cumulative impacts. There will also be a discussion of factors identified above that will influence the recovery of summer chum salmon. Some of these factors for recovery have been involved in the reductions in summer chum salmon survivals and run sizes, while others are more current in origin and likely did not contribute to the declines.

2.3.2 Ratings

Among the factors for decline, only the effects of harvest can be readily quantified. Because of this, the ranking of the various factors for decline is necessarily a subjective process. The following four categories are used to rate the various factors for decline discussed above: 1) major impact, 2) moderate impact, 3) low or not likely impact, or 4) undetermined impact.

Those factors categorized as having a major impact are ones of such significance that individually they could have caused substantial long-term reductions in survivals and run sizes. The reversal of factors in this category would likely lead to rapid recovery of the summer chum stocks. Moderate rated factors are ones that individually could cause short-term reductions in survivals and run sizes, but in the absence of other negative factors are not likely to have a long-term impact. Low or not likely ratings are factors considered to be within the range of normal survival factors for summer chum salmon. The undetermined category is used for those factors that may have negative consequences, but supporting data are not available. The ratings of factors for decline are discussed below and are presented in Table 2.12.

Table 2.12. Ratings of region-wide factors for decline of summer chum salmon in Hood Canal and Strait of Juan de Fuca streams.

Impact ratings: **UUU** Major **UU** Moderate **U** Low or not likely ? Undetermined

Factor	Hood Canal	Strait of Juan de Fuca
Climate		
Ocean conditions	?	?
Estuarine conditions	?	?
Freshwater conditions	UU	UUU
Ecological Interactions		
Wild fall chum	U	U
Hatchery fall chum	U?	U
Other salmonids (including hatchery)	UU	U
Marine fish	U	U
Birds	U	U
Marine mammals	U	U
Habitat		
Cumulative impacts	UUU	UUU
Harvest		
Canadian pre-terminal catch	U	UU
U.S. Pre-terminal catch	U	U
Terminal catch	UUU	U

2.3.3 Climate

The effects of climate on the success of summer chum salmon has three broad components; ocean, estuarine, and freshwater survival. The impacts on salmon survivals in each of these areas is influenced by climate regimes of decadal length periodicity in the North Pacific Ocean. The last documented ocean regime shift occurred in 1977, and relates to changes in local weather patterns. The Pacific northwest has experienced warmer, dryer weather conditions since 1977, and for the Hood Canal and the Strait of Juan de Fuca region, this has resulted in lower stream flows during the summer chum spawning period (September/October) and higher flood flows during incubation (October through March). These conditions have likely resulted in reduced egg to fry survivals for summer chum salmon in region streams. The impact of climate on summer chum salmon freshwater survivals is rated as moderate for Hood Canal stocks, primarily because there is substantial variability in the observed stream flows and not all years have had flow patterns consistent with negative impacts for these fish, and because the reductions in spawning flows did not occur until 1986. The concordance of the 1986 reduction in spawning flow in Strait of Juan de Fuca streams results in a major impact rating for summer chum stocks in that region. The increased frequency of damaging flows during spawning and incubation contributes to lower survivals, and is a factor that potentially will slow the recovery of naturally spawning summer chum salmon.

The impacts of ocean climate conditions on the survival of summer chum salmon during their period of estuarine and ocean residence is also important. The current ocean regime shift has changed patterns of temperature and freshwater runoff, which likely influence conditions in estuaries. Ocean water temperatures and plankton abundances in the North Pacific also have changed, contributing to strong returns of many Alaskan and Canadian salmon stocks. It is assumed that the ocean survivals of Hood Canal and the Strait of Juan de Fuca summer chum salmon stocks also have been affected, however, the data do not exist to determine the nature and degree of change. The effects of ocean conditions on summer chum salmon in both the estuaries and ocean have been rated as undetermined.

The major reduction in stream flows shown for the 1986 and later years likely has been the result of climatic change, but may still be exacerbated by water withdrawals or other human caused impacts on specific streams. Many water withdrawals and other flow altering events have occurred prior to 1968, and current stream flow patterns represent the residual water supply available after any permanent flow alterations. This analysis examined the evidence for recent changes in stream flow patterns, but did not address the overall issue of adequacy of flow for fish production.

2.3.4 Ecological Interactions

Of the various potential competitor or predator species considered, none are thought to have played a significant roll in the decline of summer chum salmon. Data relating to various salmonid, marine fish, predatory bird, and marine mammal populations have been examined for evidence of changes coincident with the decline of summer chum salmon. Only hatchery fall chum have shown a change in abundance that generally related to the period of decline in Hood Canal. Because of the large magnitude of releases of hatchery salmonids into the streams of Hood Canal during the period of summer chum decline, and because of the high potential for negative interactions resulting from these releases, hatchery salmonids have been rated as having a moderate impact on Hood Canal summer chum stocks. All Strait of Juan de Fuca potential competitor or predatory species have been rated as having a low or not likely impact. Because of recent increases in abundance, wild fall chum salmon and marine mammals have been identified as potential factors that may impede recovery.

There is a very large hatchery program for fall chum salmon in Hood Canal, and it has been posited that juvenile hatchery fall chum may have a negative competitive effect on summer chum salmon survivals. The existing evidence suggests that there is no substantive negative interaction between these two types of chum salmon, however, the question must be considered to be unresolved at this time. The potential impact of hatchery fall chum salmon has been placed in the undetermined category.

2.3.5 Habitat

The impact of habitat alteration on the summer chum stocks of the region has an unique relationship to the survival and runsize changes in these populations of fish. Habitat degradation and loss is usually the result of the cumulative impacts of changes in the land and aquatic environments. It is relatively unusual for a single habitat alteration to have a region-wide impact, and in Hood Canal and the Strait of Juan de Fuca no wide-spread habitat impacts have been observed during the recent periods of summer chum salmon decline. Individual streams have experienced cumulative reductions in habitat capacity and productivity from a variety of sources like forestry, road building, residential construction, stream flow alteration, channelization and diking, etc. Over the years this has resulted in the loss of populations (e.g., Skokomish) and caused habitat related reductions in survivals which have combined to lower the overall resiliency of the existent summer chum salmon populations. This effect has contributed to increased vulnerability of the stocks and has played a major part in the declines. The cumulative effects of habitat change have been rated as a major impact on summer chum salmon. See section 3.4 and Appendix Report 3.6 for more detailed discussion of habitat decline.

2.3.6 Harvest

Two different types of harvest have contributed to the decline of summer chum salmon of the region; pre-terminal fisheries in the Strait of Juan de Fuca, and terminal fisheries in Hood Canal. For Hood Canal summer chum stocks, pre-terminal harvests occur annually, primarily in fisheries for pink and sockeye salmon in the Strait of Juan de Fuca. The impact of these fisheries during the period of decline of Hood Canal stocks has been rated low. After 1974, an added level of fishery exploitation began to occur in the terminal area, resulting in high exploitation rates through the 1980s. Terminal harvest has been rated as a major impact on Hood Canal summer chum salmon.

For Strait of Juan de Fuca summer chum stocks, pre-terminal harvests have been rated as having a moderate impact. Exploitation rates have increased substantially in Strait of Juan de Fuca fisheries in concert with the 1989 drop in summer chum salmon escapements to region streams. There have been no meaningful terminal area harvest of these stocks, which results in a low or not likely impact rating.

2.3.7 Cumulative Impacts

Three primary factors have combined to cause the decline of summer chum salmon in both Hood Canal and Strait of Juan de Fuca streams; habitat loss, fishery exploitation, and climate related changes in stream flow patterns. An unusual feature of the declines is that the summer chum salmon of the two regions have been affected by similar factors, but the declines have occurred ten years apart. The summer chum salmon of both regions have experienced concurrent changes in critical stream flows and increased fishery exploitation rates. While this discussion has focused on region-wide change, individual stocks likely have been differentially impacted by the identified factors for decline. More detailed assessments at the stock, watershed, and management unit level are presented in Part Three.

2.3.7.1 Hood Canal

The continuous and cumulative reduction in habitat productivity and capacity influences summer chum salmon by lowering survival rates (population resiliency) and reducing potential population size. Thus it appears that when Hood Canal summer chum salmon began to experience the added pressures from climate change and new fishery exploitation, the populations collapsed. In 1979, summer chum run sizes and subsequent escapements were very low because of the effects of unfavorable stream flows on the 1975 and 1976 brood production. This poor performance was evident in chum salmon stocks statewide. The Hood Canal summer chum populations (with the exception of Union River) were the only chum stocks that did not immediately recover from the low return levels of 1979. The new post-Boldt net fisheries in Hood Canal, when combined with pre-terminal harvests, began to impose high exploitation rates on summer chum salmon in 1980, contributing to low escapements through the 1980s. At the same time, oceanic climate changes influenced regional weather patterns, resulting in unfavorable stream flows during the summer chum salmon egg incubation seasons. Spawning flows also dropped substantially in 1986 (likely climate related), and contributed to the continuing poor status of these stocks. The current low production of Hood Canal summer chum salmon appears to be the result of the combined effects of lower survivals caused by habitat degradation, climate, increases in fishery exploitation rates, and the impacts associated with the releases of hatchery salmonids.

2.3.7.2 Strait of Juan de Fuca

The pattern of decline of summer chum salmon in Strait of Juan de Fuca streams was similar to the Hood Canal experience, however, the drop in escapements occurred ten years later, in 1989. The impact of habitat alteration likely had similar negative impacts on stock survivals and resiliency. These summer chum stocks were also affected by a coincidental concurrence of changes in stream flows and exploitation rates. Regional stream flows during the spawning season dropped substantially in 1986, and likely contributed to lower returns beginning in 1989. There were no terminal area harvests of summer chum salmon in this region, however, these fish were harvested in pre-terminal fisheries for other salmon species. In 1989, the pre-terminal exploitation rates increased substantially, reducing the numbers of summer chum salmon escaping to Strait of Juan de Fuca streams. The combined effects of reductions in habitat quality, stream flows, and fishery exploitation resulted in low summer chum salmon production in the region.

2.4 Factors Affecting Recovery

This general assessment of factors for decline of summer chum salmon has focused specifically on changes in fish production and potential survival factors that occurred twenty years ago in Hood Canal and ten years ago in the Strait of Juan de Fuca. Several factors have been surmised to have had a major negative impact on summer chum salmon survivals and runsize, and others have had moderate or low impacts. Because of the time that has passed since the declines in the two regions, recovery may not involve just the factors that contributed to the decline. Some of the factors discussed above may not have had major, or even moderate impacts on the declines of summer chum salmon, but now may be factors that will slow recovery.

An example of such an impediment to recovery is the current high abundance of marine mammals in Hood Canal. Twenty years ago, harbor seals were in low abundance in Hood Canal, and are unlikely to have significantly contributed to the summer chum salmon decline. In the intervening years, the local seal population has expanded to the point that a recent NMFS review of marine mammal predation on salmonids (NMFS 1997b) has stated the possibility that pinniped predation may affect the recovery of summer chum salmon. Preliminary results from a 1998 pinniped predation study on a number of Hood Canal summer chum streams show substantial predation on returning adult salmon, and that a considerable portion of this predation is occurring on summer chum stocks.

Climate change and its affect on stream flows is another factor that has the potential to slow the recovery of summer chum stocks. The noted reductions in average spawning flows coupled with the increases in peak flows during incubation, undoubtably have had a negative impact on survivals. While not all years experience flows that are negative for survivals, the overall effect may slow the potential rate of recovery.

Depensatory Mortality

Mortality is depensatory when its rate (i.e., proportion of population that dies) increases as the size of the population decreases. This is in contrast to compensatory mortality where the mortality rate decreases as the population size decreases.

Depensatory mortality (where mortality rates increase as population size declines) is a biological factor that may also slow recovery, particularly for very small populations. Peterman (1977) has demonstrated the existence of multiple domains of stability in salmon populations, where depensatory mortality can cause population abundance to stabilize at low levels after a collapse. Predation and fishery exploitation are two factors that can affect depensatory mortality and cause a salmon population to stabilize in a lower domain, and it can be difficult for a depressed population to recover to a higher level if the depensatory processes can not be changed. Density dependent mortality may in part explain why some populations do not recover after a short term reduction in survival (e.g., the decline of Strait of Juan de Fuca summer chum salmon after four years of high pre-terminal exploitation rates). Fishery exploitation rates can be lowered in favor of the depressed population, but, it may not be possible to reduce the natural levels of predators or to rapidly restore degraded habitat that may be holding a population in a lower domain. This situation may substantially slow recovery of some small summer chum salmon populations, and in the worse cases may require that active intervention (e.g. supplementation) be used to help the population to recover.

There have also been a number of factors that are positive for summer chum salmon recovery. One is the successful reduction in Hood Canal terminal area exploitation rates, beginning with the 1993 return year. The average terminal area harvest has been just over 1% during the 1993-1997 seasons. Successful supplementation projects on two stocks are increasing the numbers of returning summer chum adults to two streams. There have also been meaningful changes in the management and culture of hatchery salmonids in the region, designed to reduce negative interactions with summer chum juveniles. The combined effects of these changes in summer chum salmon management have contributed to the increased escapements in recent years. However, additional measures, particularly with respect to habitat protection and restoration, are required for successful recovery of summer chum salmon.